

**SURECON – Compact Tailored Knowledge for the Construction Sector
Continuous Professional Development for Advisers to Building Owners in the area of
Sustainable Renovation**

SURECON Building Practice

Heat recovery, heat distribution, rainwater harvesting

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1. Sustainability of heat generation, heat distribution, rainwater harvesting

The mastering of fire distinguished humans from animals. One could cook food, heat caves and huts, produce building materials, explore metals. The open fire generated warm and thus rising air and emitted radiant heat of about 5m - but one also quickly learned that the exhaust gases are not beneficial to humans.

This knowledge led to the development of our heaters, in which we direct automated fuel and, with temperatures over 1000°C at the tip of the flame, produce warm water of max. 90°C. By means of a pump and via long pipelines and branching water flows through radiators, which should ultimately keep the room temperature to about 20°C.

Thanks to optimisation of nozzles, the boiler, control, pump and thermostat, the system was effective - but the difference from 1000°C to 20°C remained - as well as the problem of harmful exhaust gases, which are provided by the difference in temperature of the atmosphere. This applies to the finite resources of oil, gas, and coal as well as the renewable resources of wood and plants.

The goal is to cover the calculated heat demand of a house as well as a supplement for building defects and resident behaviour. If the heat demand is high due to lack of insulation and air tightness, then you need high flow temperatures that can only be produced sensibly by combustion.

If the heat demand is low,
air tightness exists and
surface heating is installed,
this reduces the flow temperature to 30-35°C.

These temperatures can be achieved by heat recovery, solar collectors, heat storage, heat pumps. Where once a unit for heating and hot water was sufficient since each temperature for the occupancy of a house was reached, several systems are now being used in parallel. This leads to higher investment, lower life cycle costs and a significant reduction in pollution of the atmosphere. Furthermore, fossil fuels are spared and can be used for more important purposes such as the manufacture of glass, clay, iron, etc.

Water is used for heat distribution and needs electrical energy in the form of pumps.

The smaller the cross-sections,
the shorter the path,
the lower the flow resistance through renunciation of arches and branches,
the lower the pump power required.

While in the past a 235 watt pump was installed, it now takes a 3 watt pump when the system is optimised.

A vacant lot requires no electricity, heat, or water, or it generates waste heat/gases, waste water, waste and transport. Rain seeps into the ground immediately and will not result in flooding. The developed land leads the surface waters of impervious surfaces into channels - the residents buy new potable water for toilets, cleaning water, the washing machine and the garden. It is therefore logical and sensible for the abovementioned consumers to filter and store the incoming rainwater. Excess water can seep into private property. Thus the groundwater regime causes no damage, and counteracts flooding.

Thus the sealing fees should be dropped, which are calculated on paved surface components to support the costs of remediation of storm sewers. This however leads to a tax injustice that must be prevented by community routes - it therefore causes a conflict.

2. Heat generation

The occupants or users of a building expect heat at a high (= heating) or low (= cooling) level.

Heat is produced where you burn something - that has always been that way.

Since we humans on Earth

- have multiplied in the last 111 years from one billion to 7 billion,
- we all expect cooled or heated houses - not individual rooms (like 111 years ago)
- we all expect sockets that are energised,
- and that everything is made by the combustion of fossil fuels,

we should not be surprised that the thin skin of the Earth (the air layer), which enables our life, is always thin-skinned. We toss approximately 100 million tons of material a day into the air.

We make a mess of it.

Now is the time to take advantage of the opportunities that arise from this.

What do we really want?

We want a comfortable room temperature somewhere between 18°C and 24°C.

Are not there smarter ways to achieve this goal?

Of course!

The goal should be to generate as much energy as possible with the building and to save in the meantime.

2.1 Fossil energy sources

To burn something: oil, gas, coal, peat, wood

Tectonic plates float like "lumps" on the liquid magma. They bump against each other and

- pile up into mountains (Alps, Himalayas, etc.) or
- slide above each other.
- Coral reefs and fish bones came by Earth movements under the Earth's surface. From the high pressures within the Earth, oil and gas can be created. The process takes a few million years.
- Forests came under the Earth: coal originated after a few million years.
- Wood grows above ground.

Everything organic which is transformed into fuels has taken in carbon during its life and stored it, which is converted into CO₂ during combustion. On combustion, the flame reaches about 1000°C.

From this, the following questions arise:

- Must we burn anything at more than 1000°C to reach a room temperature of 20°C?
- If we do not keep stocks finite for such purposes, for which do we need such high temperatures? Iron melting, glass manufacture, burning clay, etc.
- For each litre of oil we consume, our children will have to wait a few million years until they have something new.

- The release of CO₂ and CO₂ absorption regulates nature. A tree grows over many years and if it has fallen down, it takes many years to decompose.
- If we burn a piece of wood, then for a very short time we release CO₂. The advantage of wood combustion is the brief period of recovery - in contrast to oil, gas and coal - however, the CO₂ problem remains.

For over 100 years, we people more CO₂ being released than the Earth can break down again. With each fire and each heating, excess heat is created that is released into the environment.

We call the consequences climate change.

2.2 Alternative sources of heat

What temperatures do we want anyway?

Residents expect a pleasant room climate. Germany lies in a temperate climate - mild winter, mild summer - only sometimes does nature exaggerate.

A pleasant room climate in winter means a comfortable temperature:

- 18°C in the master bedroom
- 24°C in the bathroom

should be provided.

The water temperature in the shower is about 42°C; 60°C is necessary for washing up.

The history of the development of heating:

In the past, wood or coal was burned to heat water in an open vessel.

Over 100 years ago they came up with the idea of a combustion chamber = encapsulating the fireplace, closing the open vessel and pulling it to be quite long until it could be laid as a pipeline through the whole house. In the rooms, the tubes were thickened = radiator. Now the water was circulated through convection = gravity heating above 100°C.

When the energy current was invented, one could now get the water moving purposefully = pump. Now the flow temperature already ranged from 70 to 90°C. With electricity you can also directly heat water = immersion heater.

A heating system consists of:

- Energy source, energy storage chamber (oil tank, pellet container, LPG tank), chimney = flue pipe
- Pump and control
- Pipes and heating surfaces.

The energy sources

Wood, peat and coal must be refilled by hand; oil and gas flow automatically.

If wood is pressed by small worms = pellets, then they can be tracked automatically.

If we burn oil, gas, coal or wood, we produce over 1000°C at the flame tip - and turn it into a room temperature averaging of 20°C - somewhat hard to understand, right?

Additionally, for a short time during the combustion process we release the "C", which the plants and animals have taken in throughout their lives.

Are there any other sources of heat to maintain a home around 20°C?

Of course, the sun: every day it brings more than 5500 times the energy we need to Earth.

For about 50 years, one wondered if it was not sensible to use solar energy to bring water to the corresponding temperatures. Disadvantage: floating between clouds and solar panel, then you can not harvest any heat.

- Thus one needs a larger water tank to compensate for the irregular "sun harvest".
- In addition: the lower the heating flow temperature, the longer you can use low temperatures.

Available techniques:

- **Solar thermal system:** Conversion of solar energy into heat - disturbing clouds and nights.
- **Micro-wind turbines:** generate electricity. This power can be used directly in the house, fed into the public grid or, e.g. connecting to an immersion heater (this heats the water - day and night, even with clouds - but only when the wind blows).
- **Heating pumps:** When air is compressed in an air pump, it heats up. An electric air pump is called a compressor. The compressor is the central element of a heat pump. The heat pump draws e.g. from the Earth's heat, which "pumps" the compressor to a higher temperature.
- **Geothermal energy:** The core of our planet is about 6000°C warm. In some places on Earth, this temperature is very close to the surface - a practical energy source (Iceland).
- **CHP:** Another source of heat is any engine. The motor propels a light machine = dynamo, generating a "combined heat and power = CHP" heat and electricity at the same time - the CO₂ problem reappears, but the efficiency of the system is considerably better.

If we use nature as a source of heat, then we are dependent on it. So we need to store the heat - we need heat storage, e.g. lots of water. Water can store 4000 times more energy than air.

Unfortunately, we can not imprison the heat, only delay the cooling time only with a lot of insulation - after about 2 months, the heat is lost. Better than water would be oil or zeolites - but that is another issue because the technology is not yet available at low cost.

You can also save heat beneath the base plate of a basement, by incorporating a pre-construction "underfloor" under the base plate. There, excess heat can be delivered in the summer that can be recovered in the autumn and the beginning of winter - this is temporary and rather impractical for old buildings. This is also a heat generation surface for a heat pump.

If we use natural energy sources then we do not need any energy supply chamber (oil, liquid gas, wood pellets) and no chimney, because we are not releasing CO₂.

A further possibility is the use of **district heating**:

If a power plant or a company with high energy requirements is nearby, then you can direct the warm water in pipelines through villages. The houses can dock with plate heat exchanger in this system and reflect the heat there as needed.

Each heat recovery system is based on **heat exchange processes**:

Something warm brushes against something cold: the heat moves from warm to cold:

- Cold water is heated by hot water
- Cold air is heated by hot water
- Cold air is heated by hot air.
- Sun heats people, property and movables.
- Geothermal heat heats solar fluid.

2.3 The solar panel and its functions.

Panel = Collector

The radiant heat from the sun is absorbed by a black surface. Therefore, the collectors are always black.

There are two possibilities:

1. Sun heats the air:

- a. The sun heats the air in an air collector - the warm air is passed through air ducts and fans in the living spaces.

[Picture 1: Air collector, Yatego.com]

[Picture 2: TTI]

- b. The sun heats the outer walls by means of a "transparent thermal insulation (TTI)": the sun's rays are passed through glass tubes which are horizontal to the stones that are painted black. The wall is heated and functions as a wall heater.

Warm air is not productive because it cannot absorb and carry a lot of energy.

2. The sun heats a liquid.

- a. Tubes, in which there is a liquid, are led through the black surface. There is a heat exchange process taking place: the sun heats the black area around the metal tube and this liquid.
- b. Black capillary tubes: the darker the colour, the warmer an object will be. Cold water flows through the object, and then it will be warm: pool heating in summer.

[Picture 1: Flat plate collector]

[Picture 2: Pool collector]

- c. Thermosiphon: Uses the convection of warm water - no pump required. If it's freezing outside, then it freezes the system - not suitable for the German climate. Only for hot water in summer. The water storage tank is higher than the collector.

Two principles of heat recovery have prevailed for home use, although the principle of the black tubes (absorber) has been optimised:

- the flat plate collector

- the vacuum tube collector

Difference: the air between the glass sheet and the absorber obstructs the radiant heat. If one were to vacuum it off, the flat disc would break. Instead, for each black tube you take a separate glass tube, which must be "vacuum-tight" above and below - including the connections.

Through the tube flows the "solar liquid", a mixture of 60 percent water and 40 percent propylene glycol. It is up to -23°C antifreeze safe and has a boiling point of 150°C .

Altogether there are four kinds of hot water collectors:

[Pictures]

Black hoses for swimming pools The flat plate collector

[Pictures]

The vacuum tube collector Parabolic collector

The more intensely the sun is focused and strikes the solar fluid, the more heat that can be harvested. The parabolic mirrors bring it to about 400°C : process heat for production. Here flows another medium.

If the fluid in the collector is warmer than the temperature in the storage reservoir, then a circulating pump is commissioned to bring the solar fluid when the reservoir is below the panels: e.g. in the basement.

[Pictures]

The control station with circulation pump

On the way to the storage, heat exchange processes between the supply and return pipe and the surrounding air also take place. This is however not desired; thus, the pathways must be well insulated.

[Picture]

In the house, there is a reservoir in which a "helical screw" was installed. Through the screw, the hot solar fluid flows and exchanges its heat (heat exchanger) with the water content of the container.

[Picture 1: Coiled heat exchanger]

[Picture 2: Buffer tank, flamco.de]

Only in the storage reservoir should the solar liquid be cooled through heat exchange and the water be heated in the supply tank - but not to more than 95°C , as otherwise the water evaporates.

The solar fluid must not freeze at low temperatures (-20°C) and evaporate at high temperatures (150°C) - so water is not suitable.

2.4 The heat pump

A heat pump collects heat from the environment, "pumps" it to a higher level and delivers this heat to the heating system.

In this system, the connection between the quality of the building envelope - particularly the embankment lining and the air-tightness level-, the energy distribution and the heat recovery system are made especially clear.

The heat pump has three heat exchanger circuits:

- **Acquiring energy:** a cold liquid = solar fluid = bed liquid collects heat at an energy source.
- **Increasing energy:** The refrigerant is thereby gaseous (= it evaporates = evaporator) is compressed = compacted and thus heated.
- **Energy is transferred:** The return flow of the heater catches the heated gas as the heat required for the flow, the refrigerant cools down again, so that this (after it was compressed) is released and again becomes a liquid.

[Diagram]

Functional principle of a heat pump

Compression - Liquefaction - Release - Evaporation

Heat exchange

We use air, water, and special liquids and gases.

Water can save a lot of energy, about 4000 times more than air can.

- Therefore, one can not siphon off so much energy from warm air as from a wet soil.
- Therefore, water is used as an energy carrier in our heating systems.

What can save heat better?	Temperature difference [K]			1
Heat (Q) = volume x density x spec. heat capacity x temperature difference				
	Volume [m ³]	Density [kg/m ³]	Spec. heat capacity [kJ/kg x K]	Q [kJ]
Air	1	1.204	1.005	1
Cement	1	2400	0.89	2,136
Water	1	1000	0.49	4,190

Air-water heat exchanger: cold water removes heat from warm air, or hot water heats air.

Water-water heat exchanger: two streams of water exchange their heat.

Acquiring Energy

Acquiring energy from the air

- **Outside air:** We can absorb heat even from air that is -10°C warm when the liquid in the tube is colder - water cannot, it is chemically altered so that it will not freeze - you know from your car windshield washer = solar fluid.
- **Indoor air:** We suck the air out of every room or hallway/stairwell - around 20°C warm -, generate hot water for heating or for domestic hot water and discharge the cold air to the outside - but for this we need a lot of air.

Acquiring energy from the water

- If a river flows past the house, then we can take the heat from it by a coiled heat exchanger, which is encircled by the river water. In warm regions a building is usually warmer than the river water - so we can also cool with it.
- If you have groundwater beneath your feet, then you can drill 2 wells at a certain distance - suction and injection wells. The produced water is now used as an energy source, while the cooled water flows in the other wells.
 - To this end, rules must be observed that acknowledge the appropriate authority = "water authority" that guards our groundwater.
 - If all the "groundwater" energy sources were tapped into, then groundwater and rivers would so cold that no being could live.

Acquiring energy from the soil:

Up to about 3m does one refer to stored heat as solar energy.

From 3m, the geothermal heat gains intensity, as our centre of the Earth is about 6000°C hot, and also moves the heat from warm to cold => direction of the Earth's crust.

- **Vertical collector = perpendicular collectors**
Up to 100m deep, holes can be drilled - the deeper, the warmer the soil - by 2 U-shaped tubes = the probe flows the medium "sole" and absorbs geothermal energy.
- **Horizontal collector**
We dig the garden to about 1 to 1.5m in depth and lay a tube hose, Earth back on it = ground collector - collects solar energy.

[Diagram]

Ground source heat pump

Brine-water types of collector

Vertical collectors - Horizontal collectors

How deep and how many holes are needed or how big to make the ground collector depends on occupant behaviour and the energy requirement of the house.

The latter depends on the quality and the strength of the dam covering and the air tightness level of the building envelope.

Increasing energy

Within the heat pump flows a particular liquid, the refrigerant - known from our refrigerator. This is gaseous at e.g. -2°C (water at 100°C) and can be compressed well.

The refrigerant flows past the power generation side:

1. Cools it so that it can pick up heat from water, soil or air again ...
2. and heats up so much that it changes from a liquid to a gaseous state = it evaporates = evaporator.

Plate heat exchangers, more compact and more efficient than a coil - because of the larger area between hot and cold.

[Picture: Holzheizer-Forum.de]

The refrigerant in the gaseous state is then brought by an electric air pump = compressor to an even higher temperature (e.g. 60°C).

You know from your bicycle pump: at the front it will be warm when you squeeze the air = compressed.

Transferring energy

The heated gas transfers its heat in a second plate heat exchanger to the cold return flow of the heating. Here, the gas cools and heats the water to the required flow temperature.

Then, the refrigerant gas flows into a container and is decompressed = relaxed; it becomes liquid again and is once more injected into the power generation side.

The heating water gives up its heat

- via the radiator to the room air
- and is cooled from this,
- such that it must be reheated.

A heat pump requires electricity in 3 places:

- a. Acquiring energy: a pump propels the water/sole liquid/fan.
- b. Increasing energy: a circulating pump and the compressor need energy.
- c. The circulating pump on the heating side (requires each energy system).

If the building envelope well insulated, the heat stays in the house for a long time.

If the building envelope is largely airtight, then the heat is not blown "through the window".

If the heating requires a low flow temperature, the compressor does not have much work to do.

If the heating does not demand any heat, it must also not work => no CO₂.

If the construction and the energy system conform, then the gain in energy from the environment is greater than the energy loss, which is accompanied by the generation of electricity.

This is true for heating and cooling all over the world.

2.5 Wood pellets and wood chips

Wood and coal must be refilled in heaters manually; oil and gas provide an automatic replenishment.

Wood is formed thusly:

Wood pellets are small wood worms, the same length and the same thickness.

Now one can move them from a silo into a combustion chamber automatically.

[Picture]:

Wood Pellets

- Wood pellets are standardised, cylindrical pellets made from dried, natural waste wood, without chemical binding agents.
 - There are 350 providers nationwide, of which over 80 (and rising) deliver to NRW.
 - Bulk product by tanker.
 - “Big Bags” (800-1300 kg)
 - Sacks (15-25 kg)
-

[Picture]:

Fuel supply with wood pellet heating

Fully automatic boiler with screw conveyor

Fan:

Up to 20m, flexible hose, regular maintenance, preferably with reservoir

Screw conveyor:

Up to 6m, flexible or rigid, wear-free, proven low-noise technology

There are small and large pellet stoves.

Picture 1: Small stove for passive houses

Picture 2: Large stove with hot water storage tank and pellet tank

Wood chips

Wood chips are sawdust, thinly shredded trees, small branches, tree edges etc. resulting from sawing or "clearing operations" in woods and fields.

These are very unequal in size and shape and cannot logically be transported useful in small units and burned - this is only possible in large units.

Picture 1: Wood chips as wood shavings

Picture 2: Wood chips from the forest

Of course, packing wood, old furniture, etc. can also be burned, and in this case the exhaust gases should go through filters that filter out the toxic gases.

2.6 The gas condensing technology

When we burn gas, temperatures of about 1000°C are produced at the flame tip.

We heat the water heater to 40°C, 50°C, 60°C or 70°C - depending on the heating system - and this depends on the quality of the building envelope and the heat distribution.

The exhaust gas temperature is about 300-400°C.

In low-temperature boilers, the combustion and heat exchange process is optimised to the heating water such that the energy content of the gas can be better utilised. The exhaust gas temperature drops to about 150°C - the atmosphere gratefully acknowledges this.

[Diagram]:

Low-temperature boiler

Left: Heat exchanger - heat supply - gas - air - heating return - exhaust gas 150-200°C

Right: Thermal energy in the exhaust gas, which cannot be utilised in conventional boilers - gas losses - radiation and operational losses - usable heat energy - condensing - heat value

In the gas condensing boiler, the flue gases are cooled to the extent that the water vapor it contains condenses and turns into water.

Everyone knows from cooking that water can be 100°C hot - it bubbles. If you leave the stove on, then 100°C hot steam clouds will rise. The energy used in order to bring water from a liquid to a vapour state is reversed again when the water vapour is cooled to the extent that water is formed.

(Building Physics)

[Diagram]:

Condensing boiler

Left: heating flow - gas - air - condensate - exhaust gas - exhaust gas 50-60°C - heat return flow

Right: condensing - heat value - heat energy (latent and tangible) that is made usable by cooling to condensate - gas losses - radiation and operational losses - usable heat energy

The smaller the return temperature of the heating system and the exhaust gas temperature, the better the efficiency of the system.

A thermal spring is on the wall, a boiler is on the ground.

So that the condensing boiler can be used, the heater needs to run for as long as possible - an indication of the proper functioning is the failure of the formation of condensation. If no condensation occurs, then the heating begins to clock. In this case, an intermediate storage should be installed. The heating must then charge the buffer pool and therefore has longer running times.

Picture 1: gas condensing boiler

Picture 2: water outlet

2.7 CHP = combined heat and power

Engines are powered by means of gas and oil, which in turn drive a dynamo.

The waste heat of the engine is used for heating the house and drinking water and we use the electricity in the house, thus reducing the power purchasing or selling the surplus into the grid.

These systems produce $\frac{2}{3}$ heat and $\frac{1}{3}$ power. If it is possible to use heat all year round (swimming pool, production processes, etc.), this is the smartest local supply that you can imagine.

Disadvantages: the systems cost more to buy than a car engine and must be serviced.

If the means of driving is biogas, the system is largely CO₂-neutral.

It's like a car: driving consistently is better than always having the motor on and then off. Therefore, it makes sense to switch a "buffer" in between, decreasing the heat if the house needs no more.

The self-generated electricity replaces the purchased power = cost savings.

If the residents do not need electricity, they can sell it "the net" - the network operators have to lift the current. Some are nice, and pay the same amount that you pay for the electricity.

Others are less nice and pay less.

[Diagram 1]

Operating principle of a CHP

Heating network (consumers) - cool water heat exchanger - motor - exhaust heat exchanger - fuel (gas, oil) - exhaust - generator - electrical consumers

[Diagram 2]

Use of CHP's in a family house

- Monovalent operation without boiler (that is, only with CHP is it possible)

- Heat output of 12.5kW is generally sufficient or oversized
 - Buffer storage to avoid part-load and pull operation
 - If necessary, electric heating rod for some very cold days or to abandon the old boiler
 - The current can usually only be used to max. 25-30%
-

2.8 Hydrogen

Hydrogen is the smallest molecule, ranks first in the periodic table, and has one proton and one electron (chemistry class - remember?)

It does not occur alone in nature, so you have to capture and harness it. This uses up energy that needs to be generated. If it is captured, then you can gain electricity and heat by fuel cells - and we now need both.

Production:

Hydrogen can:

- be removed from water by a high expenditure of energy, for example by photovoltaics, wind power, etc., or
- the "H" is obtained from carbonaceous biomass such as plants, oil or coal by being chemically extracted at high temperatures.

One can now mix it with natural gas and transport it through existing gas pipelines.

This cycle is regionally restricted, since the "H" evaporates through the pipes of the gas system.

If the gas is obtained from annually renewable biomass and therefrom the "H" is obtained exclusively with renewable energy, then we would have a nearly CO₂- free energy.

A house is immobile, so you can use the gas pipes to transport the hydrogen.

However, we also use movables = car, boat, plane, etc., which multiply the CO₂ problem. So that it works more effectively, it must be stored and transported in small units, the "H".

Storage:

Hydrogen "H" is constantly on the run - it's such a small molecule that it travels through almost everything. One can harness it by

- cooling it to -253 ° C. Then it is a liquid and fits into a tanker - it takes about 32% of its energy content in order to achieve this, or
- pumping it at 700 bar into a bottle (12% energy consumption), or
- filling it into special containers filled with gaseous or solid substances, which can store hydrogen in their tiny interspaces.

All three techniques have yet to be practiced and optimised, as the "H" diffuses through all the container walls. After 50-100 days a metal tank is automatically empty.

The fuel cell

In the fuel cell, hydrogen and oxygen are brought closer together.

- Because electrons move, electricity is created - such as in a battery.
 - $H + H + O = H_2O$ (water)
 - This heat is released, which we can also make good use of.
-

[Diagram]

direct current

water - air

anode - electrolyte membrane - cathode

2.9 The high temperature fuel cell

In a fuel cell, hydrogen and oxygen are combined with the goal of harnessing power. Normally, a gas explosion occurs when the two elements are brought together - this is avoided in the fuel cell.

Hydrogen consists of a nucleus and an electron, which revolves on the first shell (K-shell) around the nucleus.

Each hydrogen atom looks for a partner who is willing to share an electron - the electron then orbits both atomic nuclei and thus connects the elements together.

The oxygen 8 has electrons - two on the inner shell and 6 on the second shell - it lacks two. The oxygen gladly holds out for two hydrogen atoms that are attached at an angle of about 105°. It causes water molecules possessing two electrically charged poles - like a magnet - to attract electrically when they close enough together (electric energy of binding).

If a chemical element has more than 50% of the possible electrons assembled on the outer shell, then it gladly takes more. If an element has up to 50% of the possible electrons, then it prefers to give them away.

[Diagram]

1. Water vapour

Water vapour consists of individual water molecules = $2 \times H + 1 \times O = H_2O$

2. Water droplets

Hydrogen bonding

Water droplets are very many water molecules that are electrically attracted

Neither hydrogen nor oxygen are found in nature in its purest form - they are always in binding. Thus, you need a substance that has many hydrogen atoms and a substance from which you can obtain oxygen.

Furthermore, one needs a membrane (without oxyhydrogen gas reaction) which merges regulated oxygen and hydrogen: YSZ, yttria stabilized zirconia, a mixture of zirconium ZrO_2 and yttrium oxide Y_2O_3 . Such a membrane is called an electrolyte and is capable of leading oxygen ions (oxygen atoms having more than 8 electrons) through.

The electrolyte layer separating hydrogen and oxygen, and therefore the two processes which are associated with the production of the two elements:

Hydrogen:

If you take natural gas from the gas line, the main ingredient is methane CH_4 with further components: ethane C_2H_6 , propane C_3H_8 and butane C_4H_{10} - all hydrocarbons. As natural gas is odourless, a fragrance (a sulfur compound) is mixed into all components that interfere in the fuel cell.

1. Step: natural gas passes through a cartridge, which is filled with an activated carbon: the gas is desulfurized.
2. Step: the methane is released from its accompanying gases - it is re-formed in a reformer.

Water is needed in a very pure state. For this purpose the water is sent from the aqueduct by a small water treatment plant. The water must then be heated to about $750^\circ C$. For this, the fuel cell stack is very carefully and slowly heated when switching is heated to this temperature, by which gas is burned. The process takes about 36 hours. If the operating temperature of $750^\circ C$ = high-temperature fuel cell has been reached, the other processes run even further - a chain reaction is set in motion.

[Diagram]

The main components:

Carrier plates - window frame - cell - fuel cell stack

- Operating temperature ca. $750^\circ C$
- Internal steam reformation
- Fuel economy ca. 85%
- Electrical efficiency up to 60%
- Thermal efficiency up to 25%

=>

1. Fuel cell stack
 2. Hot Balance of Plant (air and gas heat exchanger, steam generators, burner)
 3. High temperature isolation
-

1. The methane is supplied to $750^\circ C$ hot water vapour.
2. From the many carbon, hydrogen and also thanks to water vapour, oxygen atoms occur: CO_2 and lots of H_2 . The CO_2 and piece of H_2O escape through a part of the exhaust pipe. The exhaust gases are cooled as in the condensing boiler, condensate precipitates (the process is fed back) and the useful heat for heating purposes arises.

3. On the electrolyte layer, there is an anode layer. Here, the atomic nuclei of hydrogen settle, the electrons go wandering around the electrolyte layer around the cathode side - current flows.
-

[Diagram]

Natural gas => desulphurisation => reformer - removal of ethane, propane & butane <= steam
Methane & steam ca. 750°C

Methane supply => internal reformation of methane in hydrogen and carbon dioxide => reaction with oxygen ions creates electricity and forms water vapour and carbon dioxide (exhaust gas)

Anode and support structure - thin electrolyte - cathode

Air supply => oxygen -> ions => air (exhaust gas)

www.cfcl.com.au

Now we come to oxygen sets:

Air consists of about 78% nitrogen, 21% oxygen, 1% argon, and 0.04% carbon dioxide.

The oxygen is a double bond in the air in front of O₂ or O = O.

A small fan draws in air, which is passed through an air filter. Since electrons on the cathode side are in abundance, the individual oxygen atoms disengage and take two of the passing electrons, which originally belonged to the hydrogen. Thus the oxygen atom with two electrons is negatively charged = O₂⁻ = oxygen ions.

The electrolyte layer allows the forwarding of oxygen ions by being passed through the electrolyte layer, such as buckets are passed in a bucket chain, when it burns.

The oxygen ions meet the hydrogen nuclei, water and a high temperature (about 750°C, which is required for the reforming again) are created. This process takes place on the side of the electrolyte layer on which the high temperature is required.

If gas, water and air are made permanently available, then this process proceeds without further energy supply. This heat is produced (about 25%) and electricity (60%) of each cubic metres of gas. Only about 50% of CO₂ emissions are released compared to the German electricity mix.

Due to the high process temperature, these fuel cells should permanently pass through. This means that 24-hour customer care should be connected to electricity and heat.

The three treatment stages of gas, water and air must be regularly serviced or replaced. Also, the fuel cell stack will have to be replaced after a certain time.

[Diagram]

Micro cogeneration based on fuel cells (SOFC)

Energy management system - water treatment - air blower - gas treatment - fuel cell module - exhaust pipe (with integrated exhaust gas heat exchangers - not shown)

2.10 Cold extraction

We need not only heat, but also cold in residential buildings - especially if the climate continues changing.

One can use a heat pump on the one hand because it always generates hot and cold at the same time.

If you have space heaters, then you can also send cold groundwater through the tubes. If you cool the surface too much, condensation occurs in places as a result of mould growth. Thus the water has to be brought to a suitable supply temperature.

If the room temperature is too low, then you start to be cold when you enter rooms.

However, there is also the possibility of producing cold from very high heat, as a waste product obtained from low level heat.

2.11 Adsorption refrigeration

The adsorption refrigerator has four cycles:

- a. internal refrigerant circuit
- b. external "cold water" cycle (refrigerant circuit)
- c. external hot water circuit (drive circuit)
- d. external heat dissipation circuit (return cooling circuit)

The **internal refrigerant circuit** consists of water. The cycle takes place in a vacuum chamber, in which there is a vapouriser, two zeolite sorption chambers and a capacitor.

In the vacuum chamber, almost all air molecules are evacuated - it is almost exclusively water.

- Water goes from sea level, at normal air pressure = 1013 hPa (hectopascals; Hecto = 100) and 100°C from liquid to gaseous state. This heat needs to be added (2253 kJ), thus from 100°C hot water, 100°C hot steam evaporates = latent heat. Imagine a full glass of water in a glass container and vacuum out the air, then it is evaporated water at room temperature and uses the latent heat.
- A zeolite is composed of aluminum, silicon and oxygen molecules, which form a highly porous material. The pores are so small (micro/mesopores having a diameter of less than 2-50nm = 2-50 x 10⁻⁹m), that in particular the tiny H₂O molecules find space there - larger molecules do not even make it to the interior. Per gram of the internal surface area is more than 1000 m²; the length of the channels is approximately 150 million kilometers.

[Diagram]

Zeolite (Greek): Zeo = boil and lithos = the stone => Boiling stones. If steam accumulates, large amounts of heat are released = adsorption.

[Diagram]

Technology

Driving heat => heating up

Water absorption - zeolith => heat (recooling from adsorption)

Condensation => heat (recooling from condensation)

Evaporation of water <= heat => refrigeration

www.invensor.com

The process stages:

1. An **external hot water circuit (drive circuit)** heats the zeolite. The heat can come from solar panels, cogeneration or waste heat from production processes.
 2. The accumulated H₂O molecules pass over the gas phase and leave the zeolite (desorption). A small fan speeds up the process.
-

At the affiliated capacitor they are cooled so that condensation is created - the latent heat is emitted back to the **external heat dissipation circuit (cooling circuit)**. This heat is either omitted into the atmosphere or, for example, supplied to a low-temperature heating circuit.

[Diagram]

Technology

Phase 1:

Condensation - adsorption - evaporation - desorption

Phase 2:

Condensation - desorption - evaporation - desorption

=> = Cooling: Uptake of energy by evaporation.

=> = Recooling: Removal of heat from the system.

=> = Thermal actuator: Heating of the adsorber.

Tightness of welded stainless steel containers 2 x zeolite adsorber.

Water - steam - water cycle

- "Pure physics without chemistry"

- no pumps/valves

- 3.
4. The condensed water is returned to the evaporator. On evaporation, it absorbs heat and returns to its gaseous state - the zeolite is looking forward to the steam supply and attaches to it (adsorption). In this process, "adsorption heat" is released and delivered to the return cooling circuit.
5. The **external "cold water" cycle** is located on the evaporator. The water flowing past gives off heat, as in the vacuum chamber, the evaporation effect heat is needed - it cools.

Since it takes some time until the zeolite releases all the water molecules again, there are two containers which are alternately driven.

Driving motor of all the heat exchange processes is the hot water circulation = drive circuit. It lies on warm water, and then the cycle begins.

Two basic principles underlay the technology:

1. Water condenses in a vacuum at room temperature.
 - a. H₂O molecules need heat, if they want to dissolve out "water" from the composite = evaporation.
 - b. H₂O molecules give off heat when they again unite to form water = condensation.
2. Zeolites accumulates H₂O molecules in considerable magnitudes by adsorption and releases heat from this.

In adsorption, molecules of a substance attach to the surface of another substance, they do not penetrate (water glass). This daily occurring process takes place on almost all surfaces; among other things, air and water are exposed. Since no chemical reaction occurs, the process can be reversed by desorption. The heat caters to desorption.

Cold water arises because water is vapourised in a vacuum container, and in this process heat is needed - this is extracted from the cold water circuit: the water is cooling down.

The excess heat due to condensation serves as heating.

Since the zeolite is heated, it must also cool down again. Therefore, two zeolite containers are installed, which are alternately exposed to the warm water.

Driving energy is heat. The demand for electricity is low and is needed for the re-cooling fans, pumps, for controlling, for measurement purposes and for display.

Heat should constantly supplied, the resulting "cold" must be constantly dissipated.

The vacuum is checked annually, if necessary, updated.

The process and thus the machine can always be turned on and off.

<i>Optimal process temperatures</i>	<i>Forerun</i>	<i>Return flow</i>
External heat cycle	72°C	66°C
External "cold" cycle	18°C	14°C
Heat dissipation circuit	27°C	31.5°C

3. Heat distribution

The heat generated can be transported by air or you can use a means of transport, which can take up a lot more heat.

For more than a hundred years, water is used as a transporter. Water can save about 4000 times more energy than air, is inexpensive and in small quantities is very economical for a heating system.

An air conditioning system uses either heated or cooled air as a transporter. A fan must distribute the air to the directed space - drafts and dust raising are consequences.

The heat distribution should heat up/cool all rooms simultaneously and uniformly, thereby the heat should not be lost en route between the heat source and the heat chamber.

However, as not all the rooms simultaneously call for heat, the routes for the hot water are of different lengths and the heat demand fluctuates.

This poses high demands on the heat source, the circulation pump, the pipe insulation as well as the control.

The heat distribution and heat levels in a room are crucial for the well-being of the resident.

If all surrounding surfaces, floor, walls and ceiling, are above an 18°C surface temperature, we feel comfortable.

If the temperatures are lower, it is uncomfortable, and in the vicinity of the wall, we have the feeling that it pulls.

In fact, an air movement between our bodies (36°C) and a cold wall (eg 16°C) occurs. As heat always migrates from warm to cold, we feel cold.

This leads to the legitimate question: does a night setback to 16°C make sense when you need to reheat in the morning again?

Yes and no.

Yes: If the house is insufficiently insulated and air can circulate uncontrollably through the building, then at night we would produce the heat generated for the environment, because we would not benefit from it under the duvet. During the day, we want to use the spaces and inhabit them (usually without a duvet) - so the rooms must be heated.

No: If the house is reasonably insulated and built largely airtight, then it makes sense to keep the building mass of the object day and night constant. It's like driving a car: stopping and going eats up more energy than a constant speed.

Maintaining a constant temperature is cheaper than the up and down.

Why are radiators always below the window?

In old houses, the window area is always the coldest. Glass, frame material, the mounting as well as the sill and roller shutter box are the weakest points of the building envelope. To hide the unattractive radiators, radiator niches were invented. Thermography makes it visible.

If the house is reasonably insulated and the joints are sealed around windows and doors, the outer wall is no longer to fear energetically. Now it makes sense to place the radiators, which are no longer so ugly today, on the opposite walls. If the house is not too spread out then you get a new heating cycle, which includes much shorter distances and therefore has much less water content.

It is understood that the heat generation and heat distribution system is directly dependent on the quality of the building envelope: what good is the most efficient heating system when cold outside air nozzles unhindered through a building and/or the heat can easily leave the house?

3.1 Basics of heat distribution

Water can save about 4000 times more energy than air:

To heat 1m³ of water, you need to apply the same amount of energy as when you want to heat approximately 4000m³ of air.

What can save heat better?	Temperature difference [K]			1
Heat (Q) = volume x density x spec. heat capacity x temperature difference				
	Volume [m ³]	Density [kg/m ³]	Spec. heat capacity [kJ/kg x K]	Q [kJ]
Air	1	1.204	1.005	1
Cement	1	2400	0.89	2,136
Water	1	1000	0.49	4,190

Therefore, one uses water as a transport medium in the heater.

Air is not as good, air must be moved in large quantities - energy costs.

If the air velocity is greater than 0.2m/sec, then we feel uncomfortable (in terms of cosiness).

Energy saving means:

Using as little water as possible at a very low temperature

Consequences:

- The lower the flow temperature of the heating = hot water distribution, the less energy that has to be applied.
- The lower the temperature, the longer that solar yields, heat recovery and heat exchange processes can keep the building at this temperature.

Concrete and heavy building blocks can save about 2000 times more energy than air.

We humans feel good when the surrounding edifices such as floors, walls and ceilings are 18°C warm.

In the master bedroom, 18°C is enough; the bathroom has to be 24°C.

Consequences:

It is more intelligent to keep the building mass to room temperature with warm water, as to heat air by the building mass.

However that is exactly what we did in all of our old heating systems:

Water - air - building mass = 4000 - 1 - 2000

- Water is heated and flows through small-area radiators;
- The radiators heat the air;
- The air must now be brought to room temperature, the thanks to the night setback it cools walls, ceilings and floors.

Smarter solution:

- We use the building mass, in which the concrete floors, screeds and/or walls are covered with small, water-carrying tubes.

Picture 1 left: Concrete core temperature control: pipes centered in concrete slab

Picture 2 left: Ceiling heating: pipes in interior plaster

Picture 1 right: Underfloor heating: pipes in screed

Picture 2 right: Wall heating: pipes in interior plaster

- The greater the heat-distributing surfaces in each room, the lower the required flow temperatures.
- The thinner the tubes, the less water that needs to be heated => smaller cross-sections.
- The shorter the supply lines, the less water that needs to be heated => central arrangement of hot water storage and supply and return lines.

Water - building mass - air = 4000 - 2000 - 1

This means that in the planning stages through integrated planning, the energy-follow-up costs as well as energy efficiency will be determined:

Short distances - small cross-sections

If a heating system is to be renewed in old buildings, then you can disconnect the old lines and simply leave it in the walls.

- Vertical, generously dimensioned vertical cavities in the house take on all supply and disposal lines.
- As the house is going to change, cavity for other lines should be provided.

[Picture]

Planning the installation paths

Shaft in the hall

- The shafts - one or more - are disguised as built-in wardrobes and get floor-to-ceiling doors as maintenance openings.
- The shafts should be so planned that they affect all possible spaces.
- The shafts go from the basement to the attic.
- Thus each room can be provided with new lines.

So even horizontal cavities can be built. In wood frame construction, it goes without saying that before the stiffening plate plane = airtightness level, another pretext is mounted, which is reserved for the installations. In a massive house, this is taken for granted.

[Picture 1]

Planning the installation routes

- Building widely dimensioned, reversible cavities for all installations.
- The screed is not laid up against the wall, but intercepted with building boards made of aerated concrete or XPS in advance.
- All outer walls are plastered to the bottom: airtightness.
- The resulting U is lined watertight with a liquid sealing foil.

[Picture 2]

The wall installation allows the interior plaster to not be destroyed as an airtightness level.

- The screed is walled off, the remaining U-room is lined as waterproof.
 - There are all the covered wires.
-

As a vertical panel, an XPS building board is mounted on the frames and tiled.

- At the points where connectors (hose - wall panel) are hidden, tiles and carrier material are cut out (45°) with a fretsaw.
- The entire surface is jointed.
- The cut tiles are reinserted and the joints are closed with silicone.
- In case of damage, with a sharp knife separate the silicone and remove the tile non-destructively.
- Thanks to the large openings, a work at the connection points is possible.

The imagination knows no bounds when you want to hide wall installations = play Hollywood.

3.2 Heating water distribution

Hot air heating: Heated air is guided in channels up to the windows, and "swells" there from openings in the wall or in the ground.

Hot water heating:

Radiators:

- The elders: plenty of room for water, high flow temperature 70- 90°C, and a lot of warm air that rises; the surfaces radiate at each other.
- The new: little space for water, smooth front surfaces - emit radiant heat into the room; metal ribs behind heat the air; low flow temperature 40-50°C.

[Pictures]: Old radiator - new radiator

Skirting heating: A skirting board is made of metal radiators: water flows through a pipe within the baseboard, heats the wall up and down and gives off radiant heat => do not place furniture directly in front of the walls, all furniture must stand on its feet, flow temperature: 70-90°C, since the heat dissipation area is small. As the walls and in particular the transition floor-wall can be heated directly, no condensation can form = thermal mould protection.

Floor heating: A heating element is pulled quite long and incorporated into the screed => large heat dissipation surface, flow temperature 35-45°C.

Note: The greater the heat dissipation surface, the lower the flow temperature.

Wall heating: You put floor heating on the wall. Now, of course, there should be no picture, closet or curtain in front of it. The warm wall heats two rooms. The walls are not completely necessary as a heating surface.

[Picture 1]: Capillary matting heating

[Picture 2]: Heating coils in clay building board (wandheizung.de)

Concrete core temperature control: The underfloor heating is incorporated into the concrete slab, making it ideal for buildings where all the rooms have the same temperature need = administrative and production building: the heat is transferred upwards and downwards.

The rooms cannot be heated differently. In summer you can hereby be cooled.

Underfloor-ceiling heating: A doubly relocated floor heating => double laying costs, flow temperature 27°C in winter and 20°C in the summer - with the system you can also cool.

Heat pump radiators: With a flow temperature below 30°C warm air rises, so one needs 1 Watt fans. In combination with an underfloor heating or wall heating, rooms can be individually tempered, as they work with the same flow temperature.

[Picture 1]: Heat pump radiators

[Picture 2]: Fans provide upwelling

The combination of radiators and underfloor heating is senseless. The heat source must produce the higher temperature level of the heating element in order to subsequently cool the temperature of the underfloor heating again. Here, energy is dissipated.

Insulation of long pipes:

The heat to be emitted from the heating surfaces and not on the way there - that's why the pipes as well as all branches and fittings are to be insulated. For this purpose, there are appropriate fittings, which are not offered as a precaution for price reasons.

Handymen are afraid that when they name alternative or additional products they will not get a job, which is why energy efficiency is already minimised in the offer stage.

[Picture]:

The 5 Stages of Saving Energy Costs

If it's insulated, then it's right...

The hydraulic heat cycle balance

The heat should be delivered to all the heating surfaces with the same intensity. That would only work if all heating surfaces were equidistant from the power source. This is impossible, because in every home there is a loop, to which different sized radiators are connected in different rooms. If it's cold and the house loses a lot of heat, then call on all radiators to warm water. The first radiator receives an abundance of everything, while the last in many homes ends up having only cold water. Thus, each radiator must get a throttle valve, which is adjusted so that each radiator - even those dependent on removal - is at the same resistance - now each radiator receives its proportionate amount of hot water: the hydraulic heat cycle balance. The balance can be calculated by means of tables, or to be set by means of measurement. Afterwards, the client receives a "hydraulic performance report".

Circulators

1. Most circulation pumps are always at the same pressure - 24 hours a day - regardless of whether or not a radiator needs heat.
2. If the heaters are regulated through a controller, then switch the circulation pump on and off.
3. The clever pumps switch off when no water has to flow.
4. The very clever pumps note how many heaters call for warmth, and pump different amounts of water.

The pump output is connected directly to the power consumption. In the first case the pump requires approximately 100 W/h. X 24h. 150 heating days = 360KW per year.

Electronically controlled pumps reduce electricity consumption by 70-80%.

[Picture 1]: This circulation pump is at level 3 and uses 100 W per hour.

Old pump

[Picture 2]: Electronically regulated pump

Instead of a circulation pump that supplies the house, you can also connect each radiator to a mini-pump that has to supply only the radiator. A second mini-pump can flow water at an optimal amount through the loop. The energy and electricity savings are enormous, the investment costs are high - but it is a very cost-effective solution.

However: calculate first - then build.

Thermostatic valves

The heated water is transported by pump to the radiators. For this purpose, either

1. Single-pipe system: a "long line" is laid through all the rooms, or
2. Two pipe system: two lines = flow and return.

In the first case, the water must flow through each radiator, even if they are not demanding heat.

The first receives all of the water, the last usually only receives chilled water.

As a result, each radiator received a diversion = bypass. Now you could decide if the water passes by or goes through the radiator.

In both cases, maximum pump output is required. An electronic circulation pump significantly reduces the demand for electricity, and then the added value of the means-tested power purchase does not come into consideration.

Heat pumps and condensing technology are not to be used because the return temperature in the transitional months is too high, and the devices cannot deliver the amount of heat generated and go into fault mode.

The two-pipe system consists of flow and return. So every connected radiator has its own connection to the heat source (radially) and derives its heat as needed.

Now you can determine the water flow to each radiator individually and consider using hydraulic balancing equally to all radiators. The electronically controlled circulation pump "learns" that if only one radiator demands heat, it must absorb even less power in order to handle it alone.

What actually causes a heater to heat? Something must measure the air temperature and decide that it has fallen below a lower set temperature, and the heater gets warm water. Likewise, there must be an upper limit. This work fulfills the radiator thermostat, which reveals its inner secrets below:

[Diagram]

How a thermostatic valve works

The thermostatic valve controls the supply of hot water to the radiator, depending on the room temperature.

With the thermostatic head, you specify the desired temperature.

Level 3 ~ 20°C

Transmission pin

The valve regulates the supply of heating water.

Setting wheel sets the maximum valve opening. This setting is important for hydraulic balancing.

Temperature sensor compares the desired temperature with the room temperature.

In the transmission pin is a liquid or a gas, which expands or contracts due to temperature or. Thus, the valve body is more open or closed. The setting wheel located at the centre is set once by the installer after they have calculated how much heat must arrive into the room. The setting wheel works like a throttle: it does not make noise, but determines the maximum water flow rate.

On the thermostatic valves there are numbers, but no temperature information. This is because the temperature sensor depends very much on the radiator. If there is a piece of furniture standing in front of the radiator and a window sill above the radiator, then the dispensed heat does not heat the room, but rather a heat accumulation arises. The desired room temperature is not achieved. It is thus smarter to put the thermometer on the opposite wall 1.50m in height, so that one measures a likely room temperature. This would require that the thermostatic valve and room thermometer can communicate with each other. This of course:

via wireless or via cable

Until recently, there were no thermostatic valves with the setting wheel. Therefore one built a choke behind the radiator and was able to match the water flow hydraulically.

Programmable thermostats can schedule the room temperature, because the mechanism for on and off is controlled by a small servomotor: the set switching times take precedence over temperature control. Therefore, these thermostatic valves require small batteries. Thus each room can be tempered individually.

- If the temperature is lowered too much in individual rooms for reasons of cost, one must not be surprised by the formation of mould.
- Furthermore, the surface temperatures of external walls should not fall below 18°C, otherwise you get the impression that it pulls there - you feel uncomfortable when you sit there.

So: energy saving is good and important, but it must be also not be overdone.

Each pipe bend and each branch ensures that the water must be transported at a higher pressure. If our installations were hoses instead of pipes, then you would get further energy savings.

3.3 Domestic water distribution

Warm water for cooking, washing, washing, showers, etc. is required in a building.

The hotter the water, the better it can dissolve grease (washing).

42°C is sufficient for showering and washing.

At about 70°C all bacteria are killed = legionella protection, ranging once per week.

Domestic water should be stored at a central location in the house, so that more energy sources such as solar, heating or heat pump can be fed.

If all damp rooms such as the kitchen, bathroom and guest bathroom are directly next to and over one other, then hot water is there in a very short time where you want it: to the tap.

If the pipe diameters are small and the distances short, then you can save significant amounts of energy and water - and therefore money.

If the pipes are laid individually (radially) from the central reservoir to any water intake point, then no hot water is used by a consumer beforehand.

And how is it today?

For several minutes, cold water flows until the hot water finally arrives. If the tap is turned off, then the warm water is cooled in the pipe again.

At the sink, hot water is drawn off when another person just showers.

Or there is a circulation pipe: hot water flows continuously through a pipe system in a circle. If a faucet is turned, you immediately have warm water, but you need power for the pump and the water must be constantly reheated.

The circulation pump can be controlled via a timer: morning, noon, evening - if one wants warm water during the disconnection times, it takes a long time.

So: it is all a matter of planning!

3.4 Water in hoses

Water distribution can be accomplished by tubing that is used by distribution and a check valve (non-stop), installed without branch to the extraction point.

What is true for the sausage also applies to the hose: everything has an end, only the sausage - and the hose - has two. You have a clear distribution in the basement instead of many branches = Tee connectors inaccessible or otherwise concealed.

House with independent apartment:

[Picture 1]: Hot water distribution

[Picture 2]: Cold water distribution - in the middle: rainwater backfeed

[Picture 3]: Distributor in a 4-family house

Water meters count the consumption.

The more shut-off valves, the easier, faster and cheaper the necessary repairs.

Advantage of the endless hose routing:

1. there are no fittings required such as display, reductions, connecting sleeves, sheets - and no gas cylinders

2. no cutting of pipes
3. no measurement of walls
4. no soldering, which can go defective
5. laying goes much faster and is therefore cheaper
6. the error probability decreases
7. If warm water is taken, then first the cold water has to flow out until the hot water can be supplied.
8. less hot water remains useless in the hoses and becomes cold again.

This is an exciting effect that we will look at more closely.

3.5 Water distribution - the small cross-section

If you turn on a hot water tap, then first all the cold water has to flow from the pipe system until the hot water arrives.

If you turn off the water again, then the hot water remains in the pipe and is cooled - so nothing was heated (nice in winter - but in summer?). This applies to dwellings, rather than for industrial or commercial use.

If you had 10 meters between the water heater and the sink (which is a lot when all the rooms are arranged side by side and one above the other):

Material	Inner diameter in mm	$\pi \times r^2 \times l =$ content in litres	2 times per day, 365 days
Copper pipe 15/1mm	13	1.32665	968.45
Plastic 14/2	10	0.785	573.05
Difference		0.54165	395.40

The table shows:

in 10 meters of copper pipe there are 1.33 litres of water,
in plastic tubing there is 0.785 of a litre of water = about half.

Every day, morning and evening you use warm water from the sink, 365 days a year. The saved, and not in vain, heated water quantity per basin is approximately 400 litres.

Typically, an installation is done starting from a thick tube - after each branch to a consumer, it becomes thinner, until the angle valve (the wheel under the sink) has a 10mm inner diameter.

- Why not stay exactly at 10mm?
- Copper pipes have by far the highest amount of damage caused in insurance - why do we use copper pipes?

Plastic hoses are on the rise. Each manufacturer has recognised itself that the welding of and fitting of hoses makes sense, especially when every manufacturer is working with other dimensions and nothing fits nothing else except to their respective owners.

If you have opted for a system, then you are forever married to the manufacturers and installers who have this plastic welder.

And alas, the installer surrenders to his company, or his system manufacturers ...

- ❖ **Tip:** There are also ordinary pipe diameters and ordinary fittings, (known as compression fitting) which are bolted together - they can be released again and reused. Then of course you remain flexible.

3.6 Water distribution - the short way

The are directly related to the planning of wet rooms.

If the wet rooms are next to each other on each floor and one above the other in the building, then you inevitably have small pipe lengths.

Actually, the hot water storage tank, usually containing above 24°C, should be in the warmest room in the house, so that it heats the rest of the house - in this case the bathroom.

Since the containers are usually ugly and need a lot of space:

- one expects 50 litre storage per occupant (4 people = 200 litres)
- for solar use, 100 litres of storage per occupant to better absorb the sunshine fluctuations (4 people = 400 litres). Since such a container weighs about 500kg, it must be considered static.

they are usually in the basement and heat it too. However, you can also consider whether the reservoir is in the roof area above.

If the wet rooms are directly above or below this container, then we have short distances - otherwise not.

Case: solar thermal energy - support - the sun heats your domestic hot water, only works if it seems: Better that the reservoir is next to a radiator as opposed to under the roof near the collector, because the sun does not cost anything, but the fossil materials such as gas and oil do. Again, short ways to save energy.

Calculate the small savings

**every day x 365 days x 20 years
and you have a big saving.
So a house will be used for a damn long time.**

3.7 The planning

One should put in 3 water systems:

1. Cold water
2. Rainwater
3. Warm water

Whether you want to make use of rainwater or not - in any case install a separate pipe system - in the future, it is different than we imagine today.

3 different tubes are to be used:

1. 14/2mm = 14mm outer diameter, 2mm wall thickness = 10mm internal diameter for all sinks, dishwashers, washing machines, bidets
2. 16/2.2 mm for baths and showers
3. 14/2mm in for example green: for rainwater: toilet, cold water cleaning in the house, garden taps

Now you need to make a list:

1. in which rooms you have any water intakes.
2. accordingly: which tube leads where and what they are called.
3. Each tube has its own number. For this purpose we have prepared a list.

You do not need to draw up this list - is already on the next page. But only you know where the taps should be, and so you do not forget, we have already premeditated ...

Number 1	Floor	0 = basement; 1 = ground floor; 2 = first floor; ...10 = garden; 11 = garage
Number 2	Room number	
Number 3	Plumbing element	
Number 4	Hose type	

Floor	Room	Plumbing element		14 / 2 mm		16 / 2,2 mm		14/2green n RW	sewage diameter
				cold	warm	cold	warm		
.1 .2 .3 .4 .5									
0 = Basement									
0.1	Heating room								
0.1.1		Heating	cold	0.1.1.1					
0.1.2		Wash basin	cold	0.1.2.1					50 mm
			war m		0.1.2.2				

			RW					0.1.2.5	
0.1.3		Backfeed RW		0.1.3.1					
1 = Ground floor									
1.1	Guest WC								
1.1.1		Wash basin	cold	1.1.1.1					50 mm
			war m		1.1.1.2				
1.1.2		WC						1.1.2.5	100 mm
1.2	Kitchen								
1.2.1		Wash basin	cold	1.2.1.1					50 mm
			war m		1.2.1.2				
1.2.2		Dishwasher	cold	1.2.2.1					40 mm
			war m		1.2.2.2				
1.3	Home economics								
1.3.1		Wash basin	cold	1.3.1.1					50 mm
			war m		1.3.1.2				
			RW					1.3.1.5	
1.3.2		Washing machine	cold	1.3.2.1					40 mm
			war m		1.3.2.2				
			RW					1.3.2.5	
2 = 1. floor									
2.1	Master bathroom								
2.1.1		Wash basin 1	cold	2.1.1.1					50 mm
			war m		2.1.1.2				
2.1.2		Wash basin 2	cold	2.1.2.1					50 mm
			war m		2.1.2.2				
2.1.3		Shower	cold			2.1.3.3			40 mm
			war m				2.1.3.4		
2.1.4		Bath tub	cold			2.1.4.3			50 mm
			war m				2.1.4.4		
2.1.5		Bidet	cold	2.1.5.1					50 mm
			war m		2.1.5.2				
2.1.6		WC						2.1.6.5	100 mm
10 = Garden									
10.1.1	Front garden							10.1.1.5	
10.2.1	Garden	Hose connection						10.2.1.5	
10.2.2		Pond refill						10.2.2.5	
11 = Garage									
11.1.1		Wash basin						11.1.1.5	70 mm

3.8 The installation

3 people are needed. One stands in the basement and leads a hose end through the ceiling into the ground floor; one leads another into the upper floor, where the third person stands and leads the hose to the wall, where the water is needed.

The installer in the basement calls out the connection number to above, and the two others write it onto the hose - in this way, each hose can easily be identified.

All hoses are laid this way, and it is very quick - most take less than half a day.

Now, the hoses - separated between hot, cold and rainwater (each by means of a shut-off valve) - must be connected to the respective manifold.

[Picture]: Shut-off valve before it goes to the manifold.

Shut-off valve before it goes to the hose.

Lots of valves - high flexibility. If a faucet drips, then cold and warm water are turned off in the basement, and all other taps in the house can drip.

Finally, the wall plates are mounted in the wet rooms and the hoses are connected.

Cold and warm pipes are to be insulated separately! Done!

4. Rainwater harvesting

Rain falls from the sky for free. Years ago, it was normal to collect and use it. Today, it is once again modern - for use in the house and garden.

Only since drinking water is so easily supplied from the pipes to the house does one wonder how the "annoying" rainwater could be gotten rid of as easily as possible.

We can filter, store and use rainwater in the house and garden. In the house, we can use it in the WC, washing machine, as cold cleaning water and to enjoy flowers. In the garden we only need the water for pot and balcony plants (not enough water can be stored in the pots), and for trees and shrubs that don't grow in our realm. All home plants also do well without human intervention!

- Where is it sensible to collect rainwater?
- Is it clean enough?
- How much rainwater can one actually collect?
- How much rainwater does one need per year?
- And how big should the tank be?

In case of events of extreme precipitation, surface water is drained into the underground channels. Subsequently and increasingly it swells out from the vertical inspection shafts to the road surface: manhole covers dance. If one were to derive the water yield from the roof instead of the channel into a tank and use it from there, then the risk of flooding would be reduced.

If the water is used in the garden, then it seeps or evaporates. If the water flows after use (toilet, washing machine, cleaning water) into a channel, then you have to pay for it. After all, the channels below the ground belong to the people - and we are the people; we paid the investment and must also take over the cleaning and maintenance costs.

Thanks to reduced water consumption and new, over-sized wastewater treatment plants, different channels require additional flushing so that everything flows.

If there are two manhole covers on the road surface in the immediate vicinity, then there are two lines: rainwater management - goes unfiltered into a river - and a sewage line - disappears in the wastewater treatment plant.

If there is only one cover to be seen, then everything flows into a canal. It runs through this channel, then it comes to flood through sewers in the house with malodorous consequences, almost certainly with mould and bacterial contamination as a result.

Solutions in the following chapter: climate change - flood = heavy rain.

4.1 Calculating rainwater

Rainwater is available for garden use as specified by the advertising in particular. This makes very little sense. The main rainfall is in spring, autumn and winter, when the garden does not require additional water.

Rainwater in the garden need only be used in flower pots and plants that are not used to dealing with the local weather conditions - and only in summer.

In 1 hour approximately $1\text{m}^3 = 1000$ litres of water flow through a $\frac{1}{2}$ inch hose - did you know this? Most chosen rainwater tanks are too small for this task, because what use is a 1000 or 2000L tank? It is enough for 1-2 hours of blasting operations.

Hygiene

Collecting rainwater from the steepest roofs possible - the water from flat roofs does not flow fast enough and thus contains more organic components:

- When birds fly, they also lose something. This "something" ends up on the roofs; if you are unlucky, on your head.
- Dust flying through the air settles on the roofs. Above a certain amount, seeds land and begin to germinate - the roof is covered in moss, or green.
- The smoother the tile (e.g. glazed) and the steeper the roof, the less moss, the lower the pollution in the water.
- Thanks to our combustion activities of oil, gas, coal, we release for example sulfuric acids - each only a little, together quite a lot - to the air. This combines with the rain and falls back to Earth. The rain is so sour - to us humans?

Conclusion: The rainwater is not to be obtained bacteria-free or free of pollutants - so it's not as clean as our drinking water. Therefore, rainwater is also gray water and must remain quite strictly separated from the drinking water - in all pipes.

Copper roofs are not suitable for rainwater harvesting; even copper gutters lead to deposits in concrete tanks, which can and must only be removed by very costly sandblasting.

Rain yield:

1. One can find various publications on the amount of precipitation that falls in a year in an area of the sky - the "Civil Engineering Department" and the "Lower Water Authority" give your precise information about your region. An overview map:
[Picture]

2. If a light drizzle falls on hot tiles in the summer, the water evaporates; if a snow avalanche slips in the spring from the roof, or if a heavy rain falls with strong gusts of wind in autumn, then it is understandable that not everything ends up rainwater in the gutter and flows through the downpipe. Also, the downstream rainwater filter does not filter all the water. It is estimated that about a 25% loss (= 75% of the statistically recorded rain) gets filtered into the tank.
3. The rain collecting surface area is calculated according to:
House width + roof overhang + gutter
times
House length + roof overhang
4. The rain comes from above. What matters is the horizontal rain collecting area, the roof angle does not matter.
5. Add all roof surfaces.
6. The expected rain yield for one year on all roofs is:

$X = \text{sum of all roofs} \times \text{rainfall} \times 0.75$ (= 75% of filtered water in the tank)
= rainwater yield

If we assume a 100 m² roof area and the average rainfall in the area around Cologne

700 liters = 0.7 m³ = 70 cm of water per m² and year
then

$X = 100 \text{ m}^2 \times 0.7 \text{ m}^3/\text{m}^2 \times 0.75 = 52.5 \text{ m}^3$

Rainwater consumption

The only truly regular consumers of rainwater are us residents. On a daily basis we need water for the toilet, washing machine, to clean, and not as regularly as water for houseplants. For these purposes, can also use this "gray water".

Gray water is not as clean as the "drinking water" from the pipe - because this must be free of bacteria and other contaminants.

How much rainwater can minimise the purchase of drinking water?

Per person per year (statisticians have calculated):

Washing machine	7m ³
WC	6m ³
Cleaning	2m ³
total	15m ³ and year

A 4-person household needs about 4 x 15m³ = 60m³ rainwater.

In a region with 700 litres of rain the optimum roof surface is:

$X = 60 \text{ m}^3 / 0.75 / 0.7 \text{ m}^3/\text{m}^2 = 115 \text{ m}^2$

For 4 people, you will need a rain collecting area of about 115m².

Tank size:

Rainfall alters due to climate change: the dry periods without precipitation last for 6 weeks and sometimes even longer, the rainfall in some rain events (or floods) reached such high values that they were previously unknown in Germany. This means that the tank must be larger, so that the water will last longer.

The tank should be able store water for at least 6 weeks = 1.5 months:

1. Number of residents x 15m³ / 12 months x 1.5 months = amount to be saved.
2. Since in a tank about 500 litres of water at the bottom of the tank remain unused for deposits, this value is added to it.
3. The given tank size does not match the industrial water amount, since the water is not impounded until fuel cap is empty at a volume of 500 litres.

Choose a tank size:

amount to be saved

+ 1000 liters (= 1m³)

and opt for the next larger tank.

Let's stick to the above-described 4-person household:

4 people x 15m³ / 12 months x 1.5 months = 7.5m³ + 1m³ = 8.5m³.

A tank of 9-10m³ is appropriate.

Special cases - not so rare:

- a. If a roof has a smaller rain collecting area, then it is not worth the connection of all consumers. In this case, the tank size depends on the rain collecting area.
- b. If a roof is larger, then the tank can be made larger, the better that climatic changes can be bypassed.

Basically:

1. The water in the tank should be as free of debris as possible
=> Filter in front of the tank.
2. The collected water cannot be exposed to UV radiation, otherwise the water will turn green and become a mosquito breeding ground;
typical case: aboveground tank in the garden
=> Min. black tank walls, lid on it and completely in the shade.
This water can be used only in the garden.

3. The water should be stored in a cool place so that the organic components are not brought to life on the tank bottom
=> Tank in the ground.
4. The water in the tank should remain in as gentle a motion as possible. This happens by water supply and water removal. The water supply is sporadic, the water intake regular. That is why we advocate water extraction above the sediment layer, i.e. near the bottom.
5. A proper stainless steel pump in the tank (it must pump the water) cannot be heard and lasts longer than a domestic water supply above the Earth's surface (must suck and pump).
6. Filters should be inspected annually, the tank should be regularly inspected, and everything should be cleaned every 5-7 years
=> Enables access.

If friends, neighbours or installers point out the danger of odorous laundry or corners of the bathroom, then they have violated the abovementioned principles.

4.2 Why harvest rainwater?

In all environmental relieving techniques there are always several perspectives:

- Why should I do something when the others do not join in?
- Is it worth it?
- I think it's great, but I cannot afford it
- I do this out of conviction.

Let us consider the use of rainwater:

- ❖ Total cost of investment: €4000-8000
- ❖ Savings per year: for example, 60m³ shopping for drinking water x €2.50 = €150
- ❖ Your system consumes electricity = you do not save much.
- ❖ Amortisation: e.g. €6000 construction costs / €120 annual savings = 50 years
- ❖ Thus it is clarified: the investment really does not pay off.
- ❖ The system affords you with conviction!

In the area south of Frankfurt, so many people live cheek by jowl that all incoming rainwater is directed into the Rhine - nothing seeps anymore.

If there is no water in the ground, you can also extract none.
However, many people need a lot of water.

One collects drinking water from very deep layers, whither the water is bequeathed only after several hundred years - that is not a solution.

So you pass the Rhine water across fields, let it seep away and then it has a topsoil, which is disposed as hazardous waste - this is also not a solution.

Who pays for all of that? - Of course, us citizens!

Nature has gained the know how over the course of thousands of years that it makes the most sense when incoming rain also seeps exactly there.

We humans are naturally smarter and seal the surfaces, channeling rainwater, channelling the rivers, building as close as possible to the rivers. If more water falls than we anticipate then we have a problem: a flooding problem.

So we citizens pay for channeling, now we pay for the flood damage and then the "restoration". We can allow all of this, if we have enough money.

Or we start on a small scale - each in their own homes - to **not** build against nature but rather with it.

- a. If a plot of land tolerates the size **and** the ground of the water absorption capacity, then all stormwater can seep in. When properly planned, far fewer costs arise than having a corresponding channel connection.
- b. If a big rain falls, the garden needs to deal with it, because the rain just flows along with the collected roof water into the garden.
- c. This problem is minimised by buffering the roof, and water is continuously consumed - now the whole technique is reasonable and logical.

However: if the idea is found to be good, but is not affordable at the time, then you cannot do anything - except:

- Infiltration in your own grounds and
- Preparation of a system in the house.

If there is a compulsory community rainwater connection, then you have to comply with this.

Preparation in the house

Rainwater = gray water and drinking water must be kept strictly separate in the house - for hygienic reasons. When passing gray water through water pipes, bacteria can multiply in the drinking water pipes and even go against the flow direction of the house in the public drinking water system. To rectify (clean) this is a very expensive proposition for the rainwater users - who only meant well.

There must be a hose laid at all rainwater consumption points - see previous chapter -. There must be no mergers.

If a rainwater harvesting system is completely planned but built immediately, then you quickly realise what preparations are cheaper to implement now rather than later.

Regions with expected future drought and regions with an oversupply of rainwater would be ideal for this technique, as everyone's rainwater tank serves as intermediate storage and protects the environment.