A solution for the global Energy Transition

saving 30% of Germany‘s energy

a built, tested,
exceptionally successful
and forgotten concept

Gravel heat storage

below a buildings foundation

Gravel heat storage

a naturally grown material

Gravel heat storage

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Technology readiness level

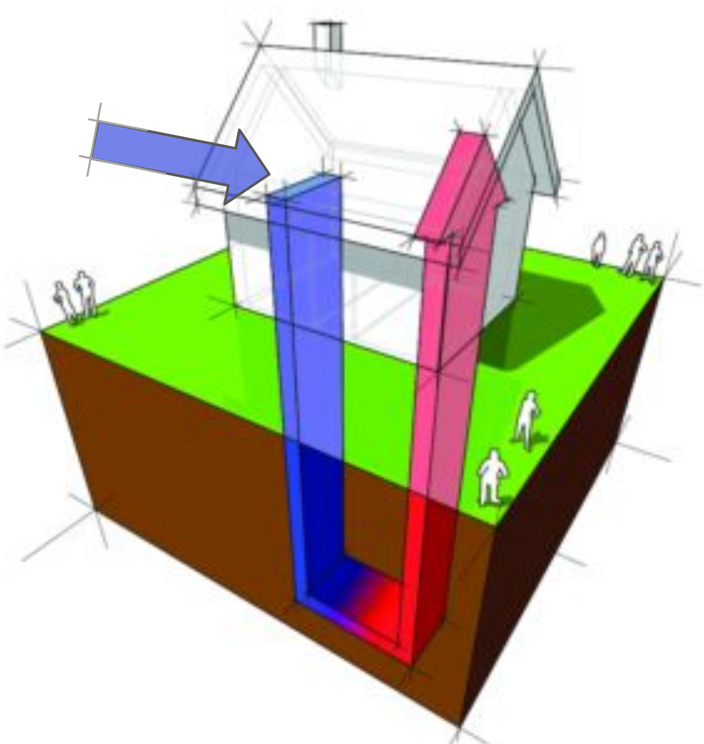
- no further research and development required
- air is channeled through the ground below a building to store heat energy in gravel and the surrounding ground.
- the system is suitable for all climates.

If the climate is too cold additional energy from deeper geological strata has to be accessed, or heat pumps used. If the climate is too warm the system will mainly be used for the cooling and less to store heat in the most optimum way.

- the system is suitable for all types of buildings and also for retrofitting.
- any ordinary construction company can do it without special, or additional training or equipment.

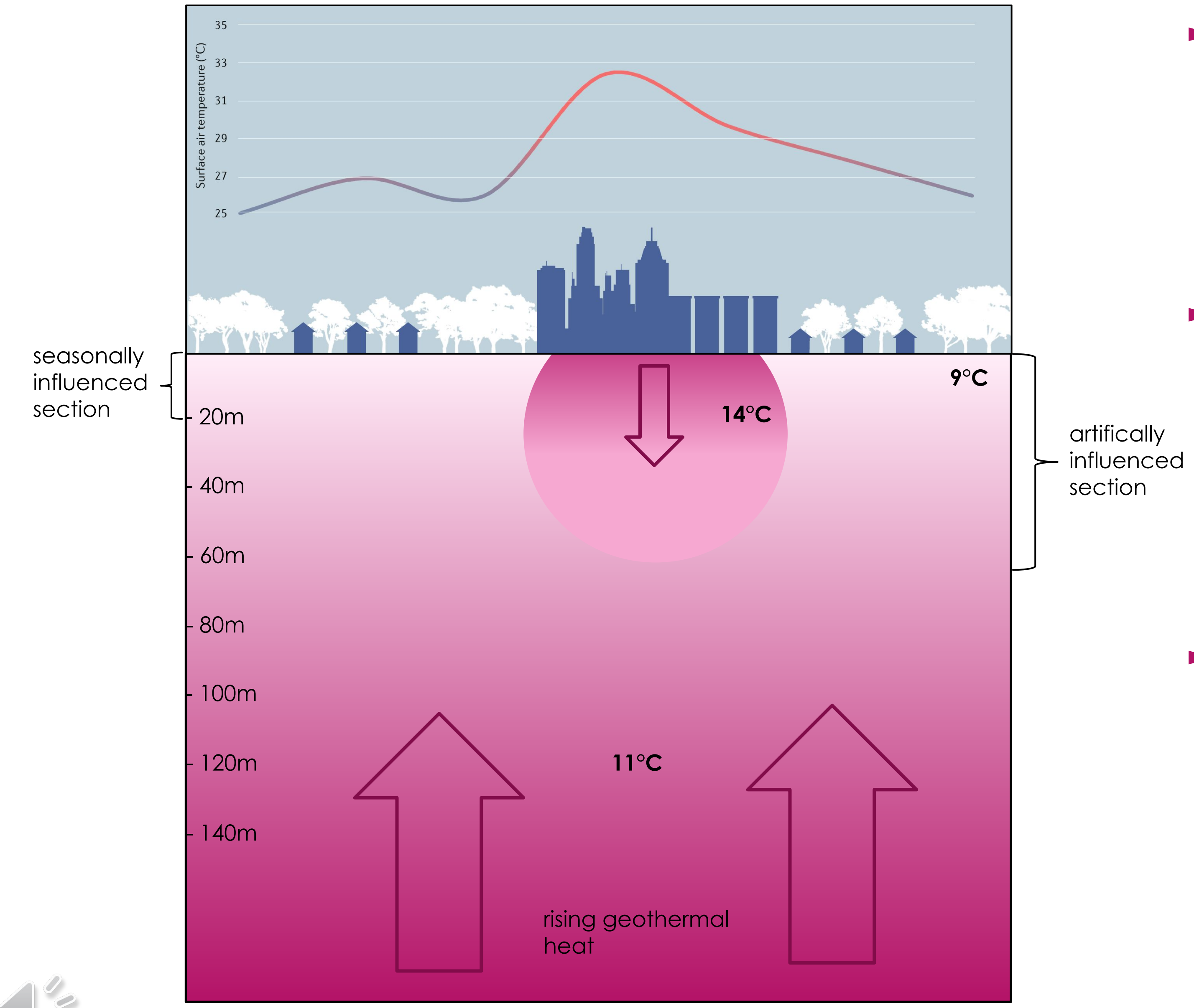
potential

- with this system 30% of the entire energy expenditure, which is for heating, can be saved in countries with temperate climate like Germany. Savings for cooling and ventilation are additional. It is more simple, cheap and scaleable than most of the much courted technologies in the media.



- energy requirements for cooling are rising due to global warming and rising standard of living. It might be higher than the heating demand before they mid of the century.
- the system provides fresh air to buildings increasing health and work performance.
- tens of thousands of contruction companies per country are able to realize a swift roll-out of the gravel system. It can be as fast as new construction plus refurbishments.

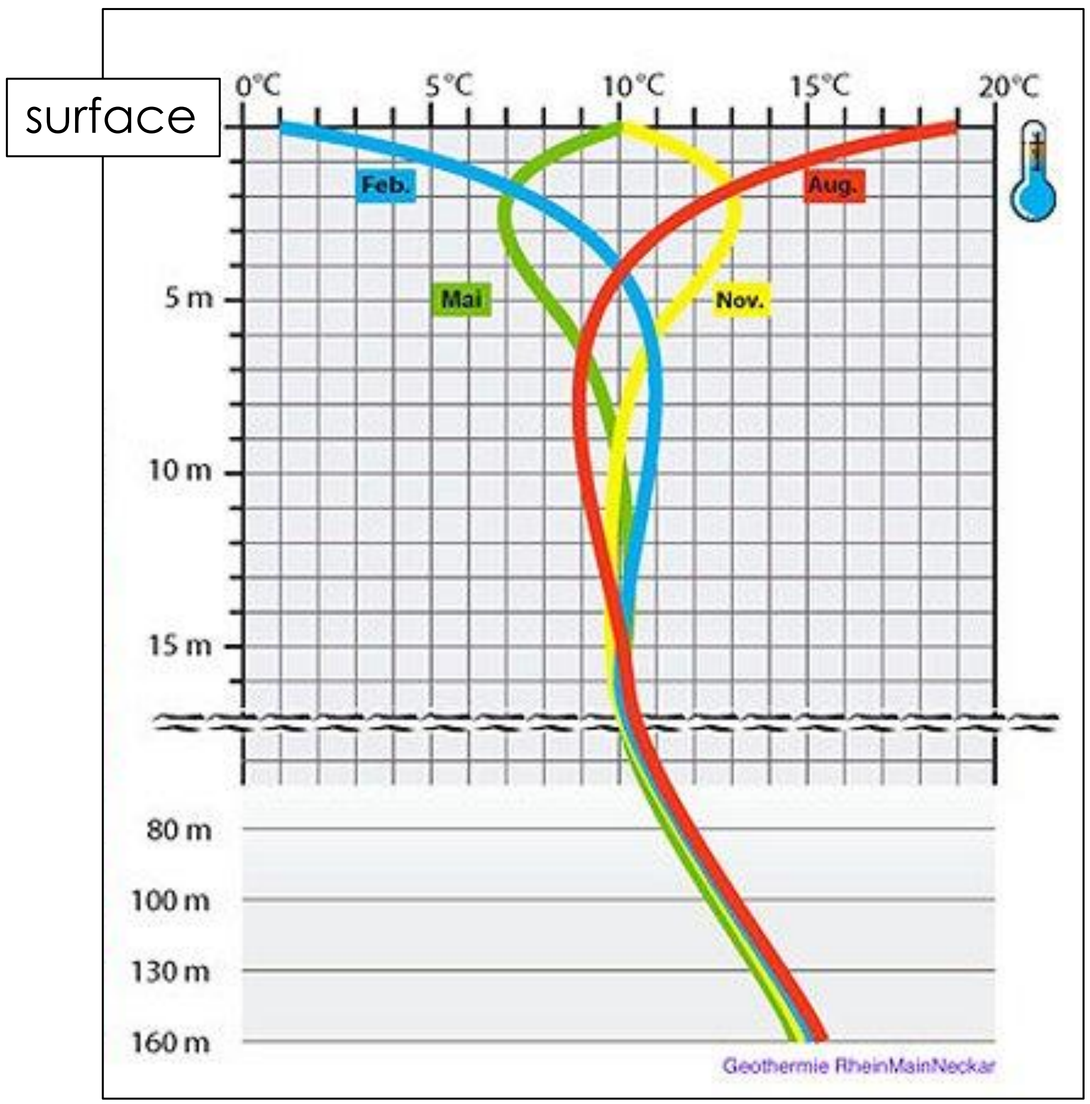
ground as storage



- the picture shows the difference between natural heat in the ground and the effect of buildings adding heat.
- the gravel storage system would add more heat energy and raise the temperature in the ground to >30°C dependent on the location.
- this allows for buildings to work without a central heating unit and without the use of fossil energy, thus reducing constructional and operational cost.

heat sources

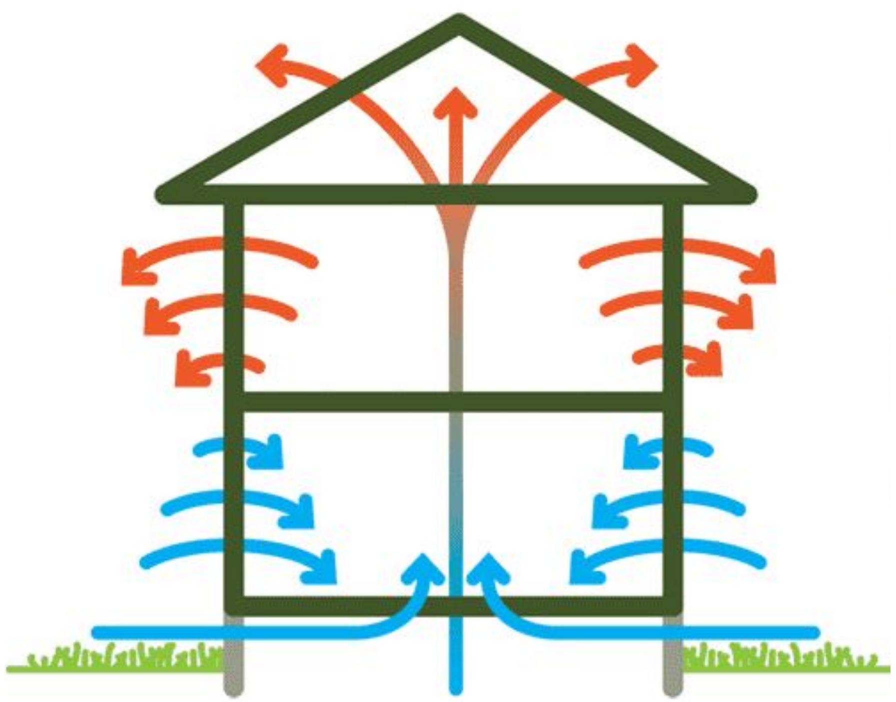
natural ground temperatures



- energy from ground, air, rain, waste water and electricity surplus in the grit can be stored in the system.
- the natural states of the ground are completly changed, because the entire ground under the building is activated for heat storage.
- hot air intake in summer leaving the gravel storage at 30°C is not used for ventilation but exits through a chimney on the buildings West side.

passive cooling

- a building can be cooled and provided with fresh air the same way a tree pumps water from the ground: An open window or air vent creates suction. In consequence air is pulled into the appartment from the outside. The stack effect is the driving force.



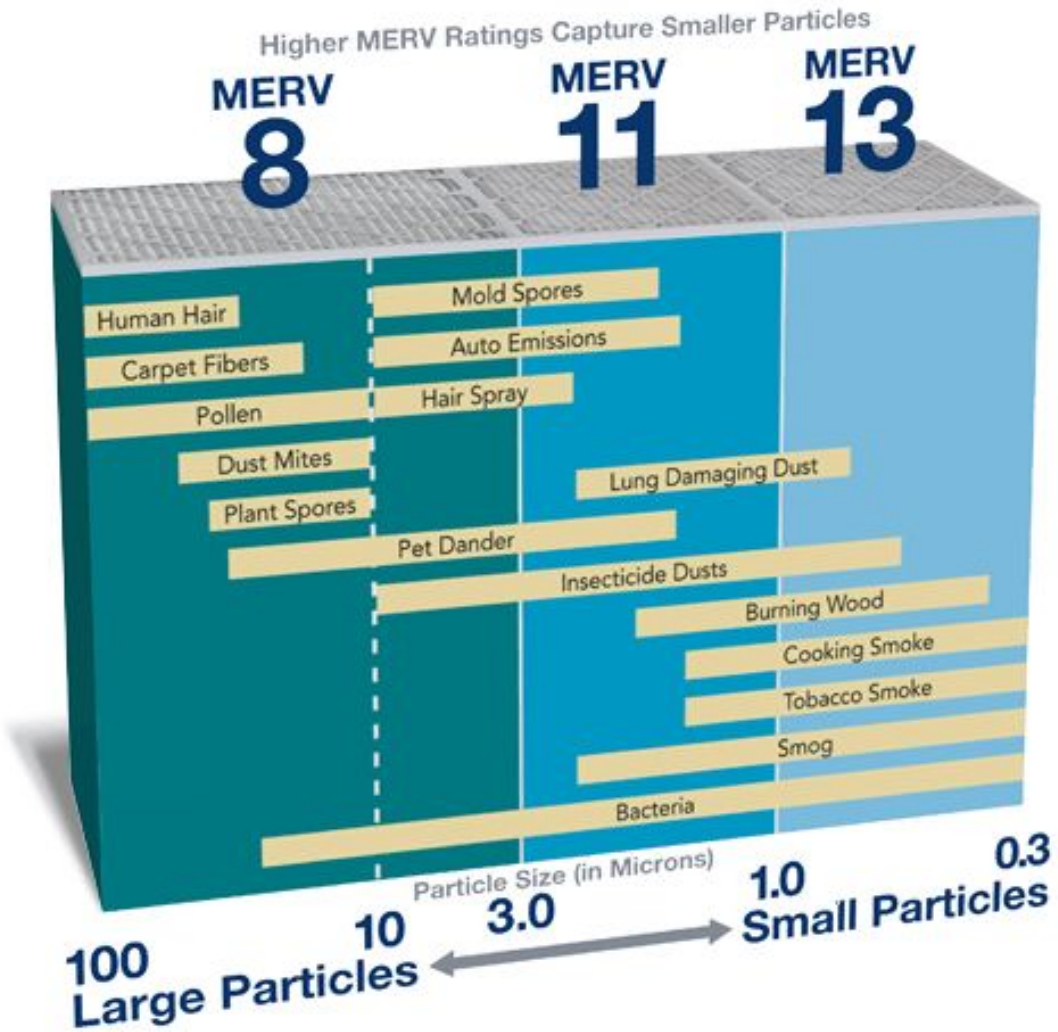
passive means:

Tech-free or low tech and no or little electricity demand. It can also mean automatically adaptive.

air purification

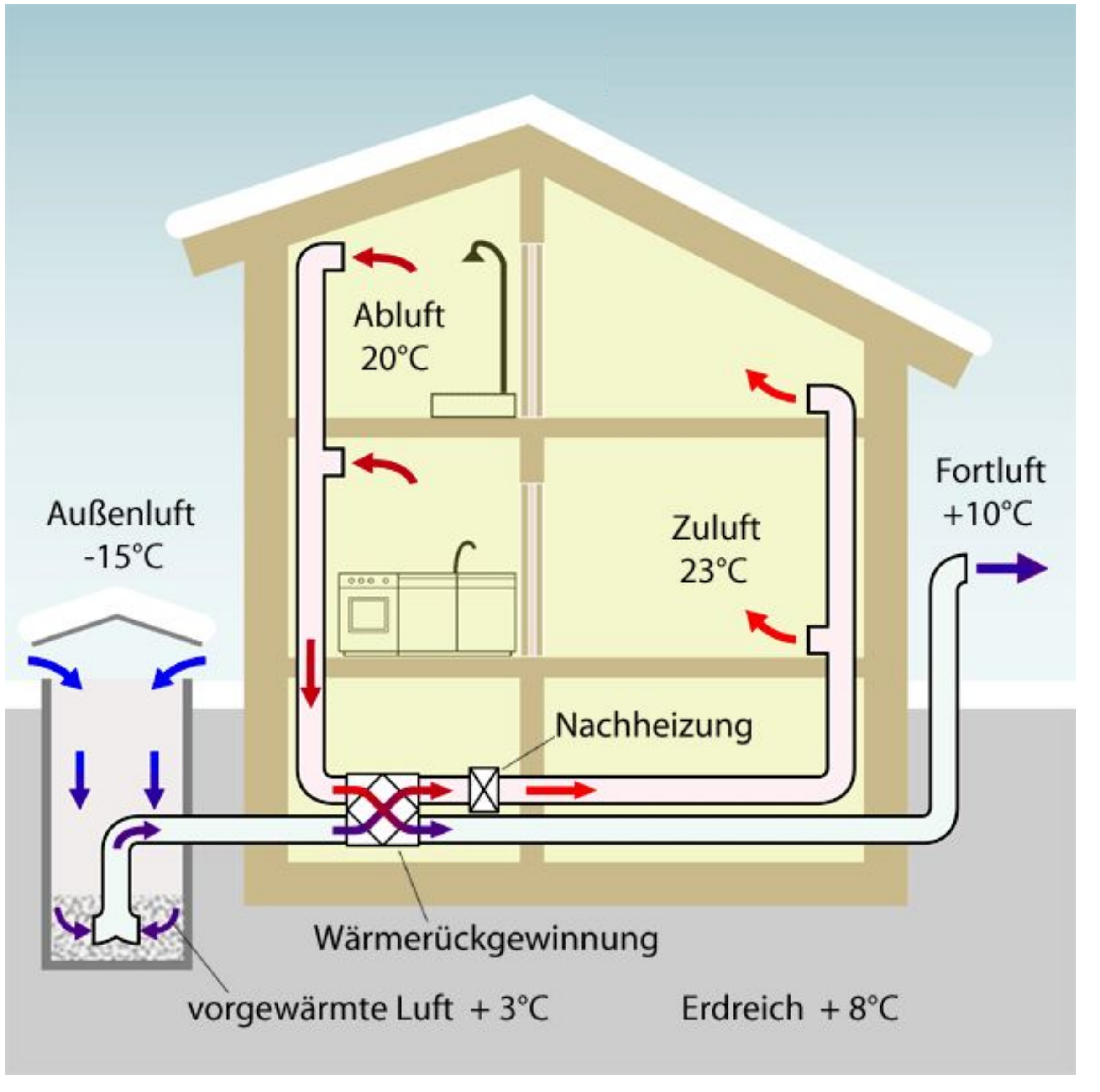
- the system provides fresh air to a building. The air also carries cooling and heating energy. Either service can be the primary one.
- the system provides air purification by contact with gravel, mineral soil and possibly charcoal.
- in addition technical air-purification on the intake and on the outlet to rooms should be considered for complete and controllable air purification and quality.

The purification might be filters for fine-dust, micro-plastic and flue gases from fires are suitable for the intake. Filters for microbes are suitable for the outlets. These filters hinder the airflow and require fans to keep the airflow up.



Air wells

- the presented system provides purified air for breathing. Similar systems are called Airwell.
- Airwells purify the intake air from contaminants like Ozon and Pollen through layers of gravel, sand and soil.
- air humidity is passivly balanced.
- if the ground produces Radon the Airwell has to be additionally sealed.



advantages (physics)

- the system works with direct contact, much more efficient than regular heat-exchangers. The air comes in direct contact with the gravel storage and heat-transfer is direct. It is the same concept that the *Rotational air heat exchanger* is based upon.

- fresh air is released directly into the air inside the building. This is much more efficient than letting hot water heat a radiator which is then in contact with the indoo air.

- The system uses the high summer temperatures of up to 40°C to store large amounts of energy underground. The hot air intake would be shut off below 25°C outside temperature.

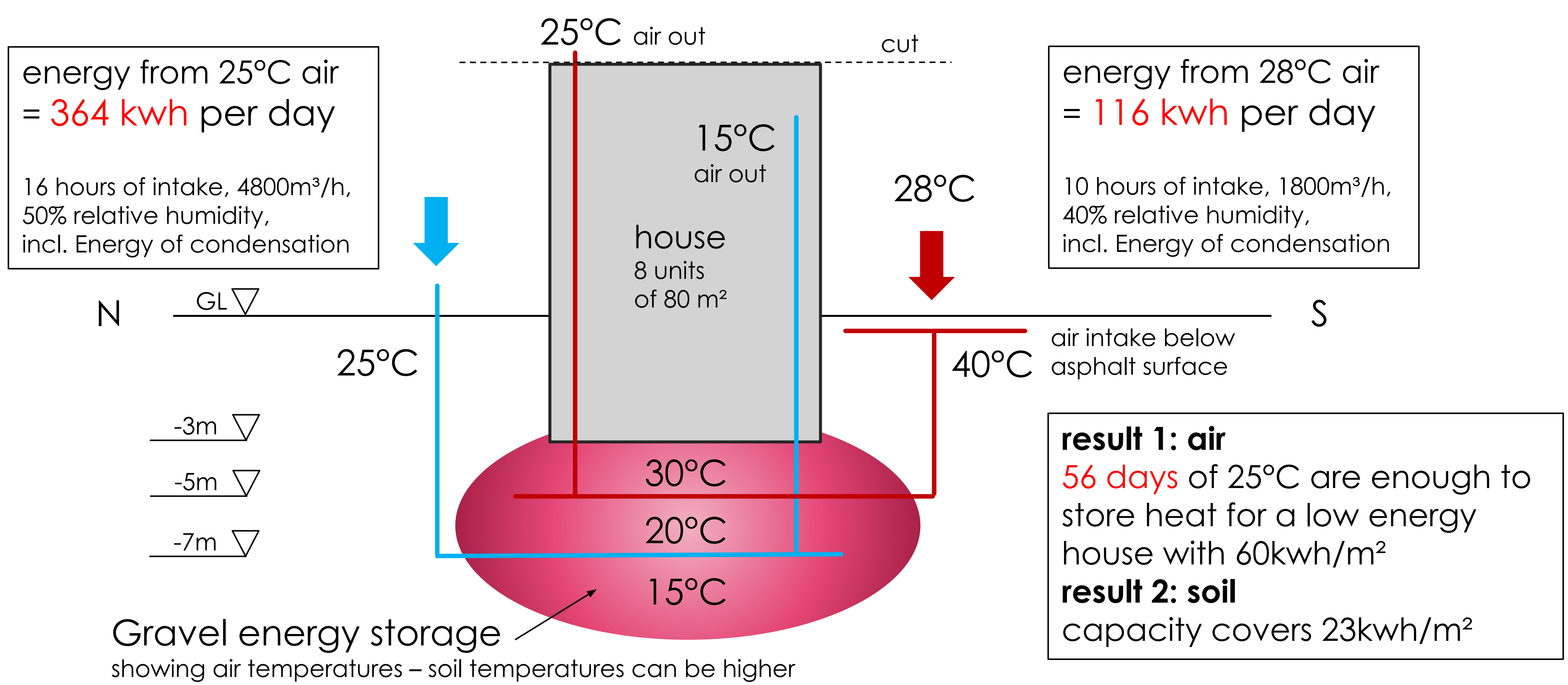
comparison

- the air canals in the gravel system have an energy transmitting surface with the ground <u>hundreds of times larger </u>than heat exchangers working with small liquid filled pipes.

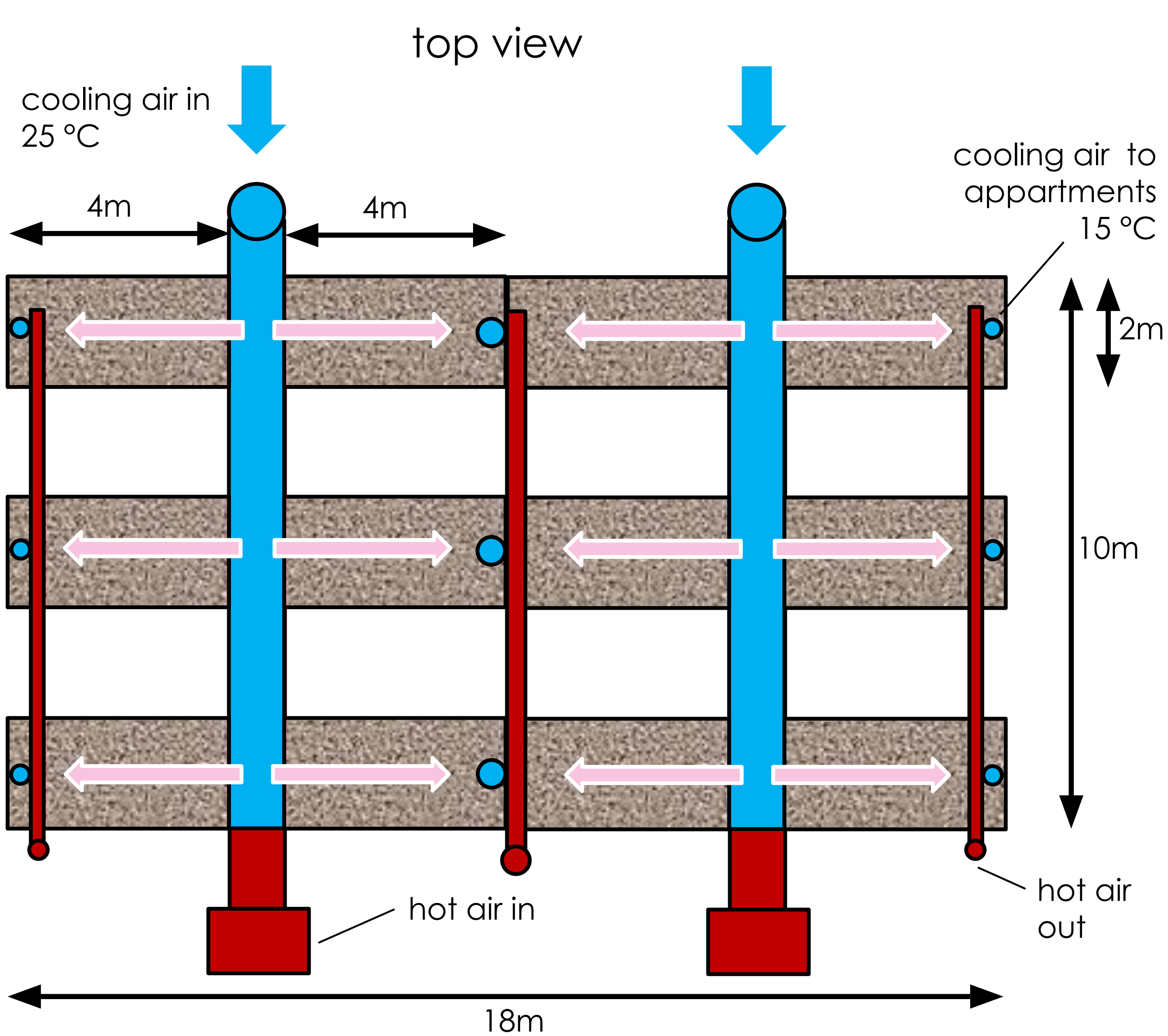
- the system is thus fundamentally different from the use of Geothermal power. Geothermal power, close to the surface, delivers lower temperatures and requires a heat-pump with all of the disadvantages.
- air heat pumps use up an entire section of the garden around a house. They emit noise and can not be integrated into a natural landscaping concept or architectural aesthetics. They are expensive, require lots of electricity and use dangerous chemicals.

heating & cooling

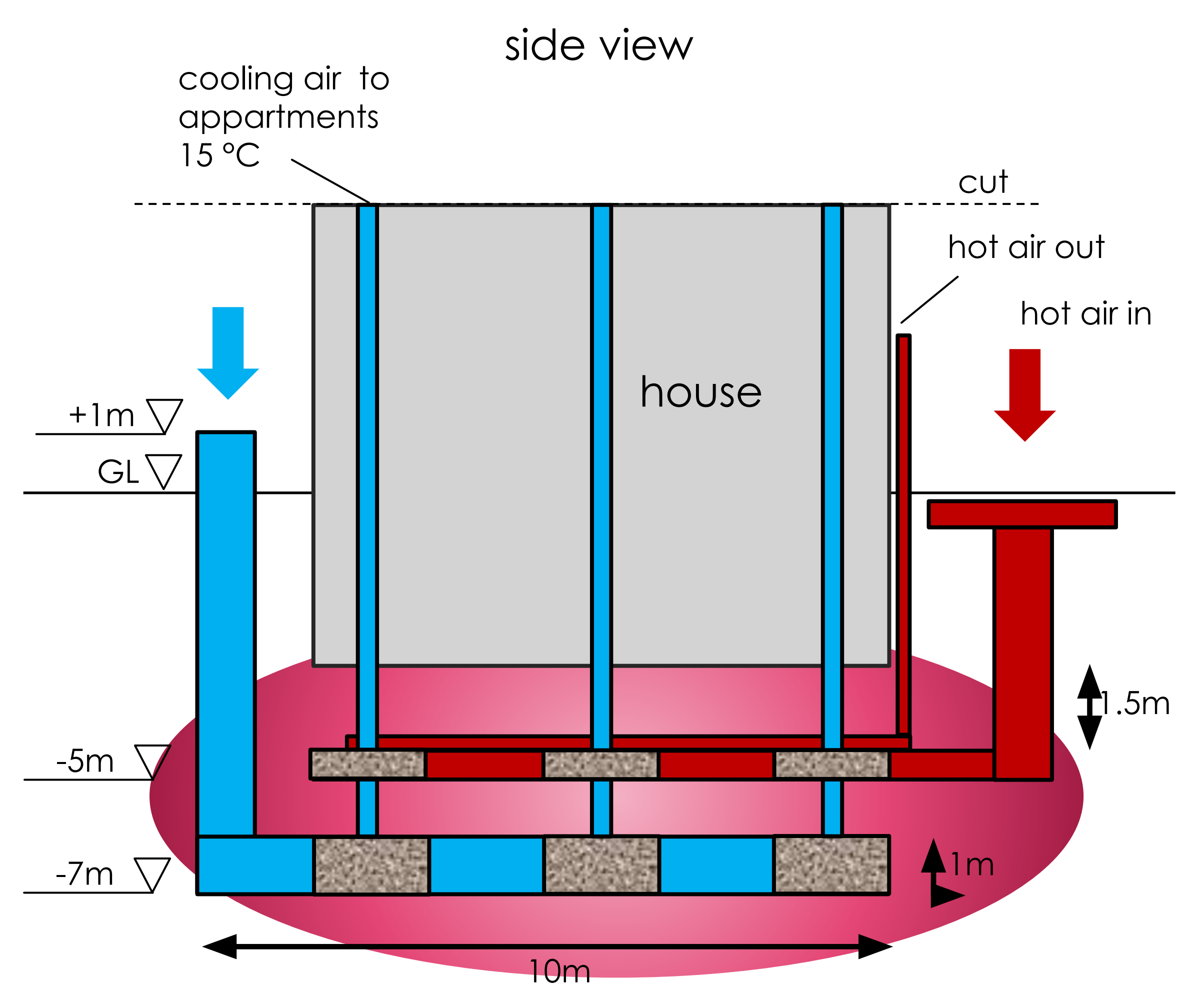
- during summer the air-intake for cooling is on the North-side of the building, in the shade. The air-intake for storing heat underground is on the south-side of the house, in the sun.



air channel layout



the 12 channels allow for short passage and even distribution. Together the crossection is 24m², of which 10m² is open for airflow. This geometry results in 0.1 m/s of air speed, slow enough for passive flow.



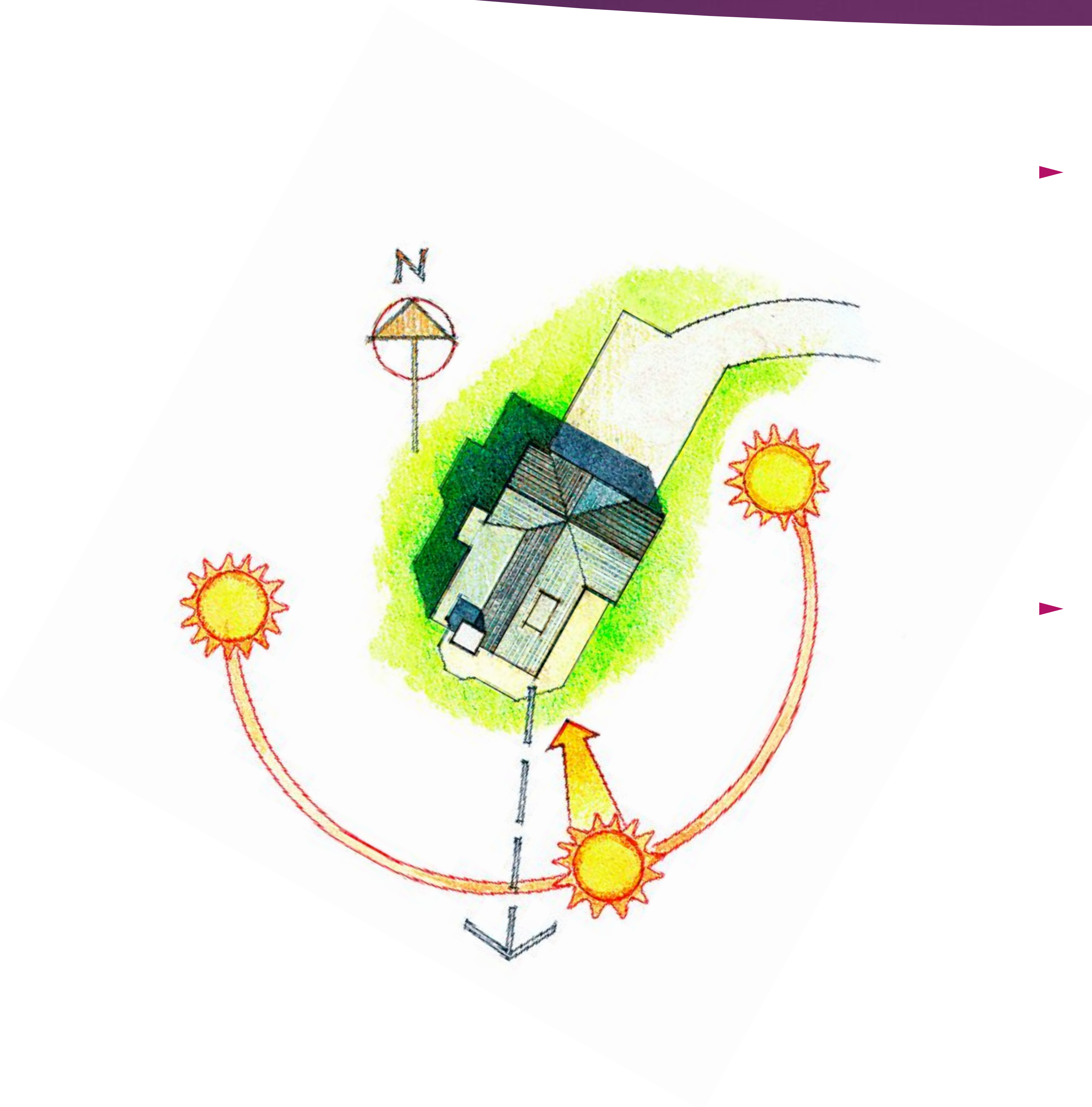
The cooling air channels are used for heating in winter. The system holds 210 tons of gravel and is surrounded by 1400 tons of soil. The gravel can store 0.55 Mwh of energy, the soil 9.2 Mwh. This would mean 16kwh/m² is provided for heating - passiv house standard. But no storage is required for 30 to 50% of the year in which energy in/out is happening between day and night.

water generation

- warm air transports moisture into the ground delivering even more energy by condensation. The condensate has to be extracted from the channels. This is done with a simple system for water evacuation also dealing with possible flooding events.

- water is delivered to the on-site Rainwater Management system (for garden irrigation). The system provides water in any region of the world. The amount of water, according to the model on a 25C° day is 1100 Liters.

orientation & condensate



- the air intake on the North side can be combined with evaporative cooling and shading of trees. The air intake on the South side can be combined with hot surfaces like an asphalt drive way or solar cells.
- the water evacuation system can be connected to Rain-Water Management, part of any Eco-Smart Home. This means that any water from the gravel channels is used for irrigation of the garden, or for flushing of toilets.

(higher water quality like for showering is harvested from the roof of the buildings and filtered)

combinations

- variants of the system are easy to combine with other heat storage types like high-temperature electricity-to-heat or solar thermal appliances. It can be linked to a Smart-boiler connected to a virtual power-system. It can recover the heat from grey water sources (washing etc.)
- a large storage tank for warm water can serve as additional seasonal heat storage. Sometimes warm rain, further heated in contact with the roof‘s surface to considerable temperatures above 40°C.
- the annual amount of warmwater from the roof of the 10m by 18m model house underlying this presentation is 20m³ . Enough for a seasonal heat storage providing a percentage of the heating demand.

seasonal heat storage with water

flood control

thermal input of water

flood & drought control

- in regions prone to flooding the system can function as retention utility and likewise to recharge the ground water for means of drought prevention. In these cases water does not have to be pumped out from the gravel channels.
- the same applies to regions with rainy and dry seasons.

retention swale as landscaping element

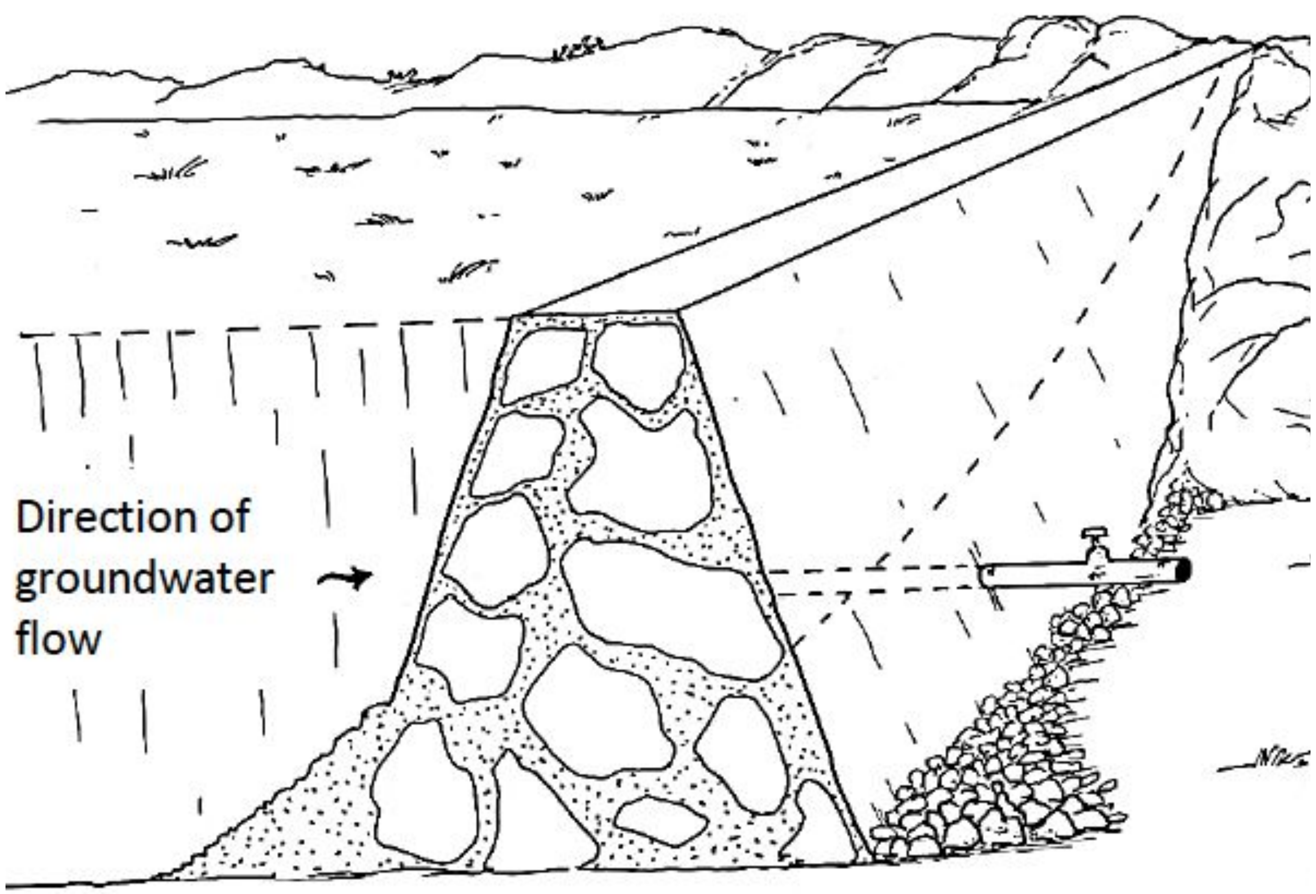
Developmental aid

- many countries have high temperatures in the rainy season and cold weather in the dry season. So capturing warm rain and heat from roofs and storing it would provide heating energy for the dry season:
- houses in those countries are not insulated and do not have a central heating unit. Temperatures in even the modern buildings fall as low as 9°C in the morning.
- in context of developmental aid this is important because not only is demage by annual floods high, but also because there are catastrophic water shortages in the dry season.

warm rain on a hot roof in a village

water purification

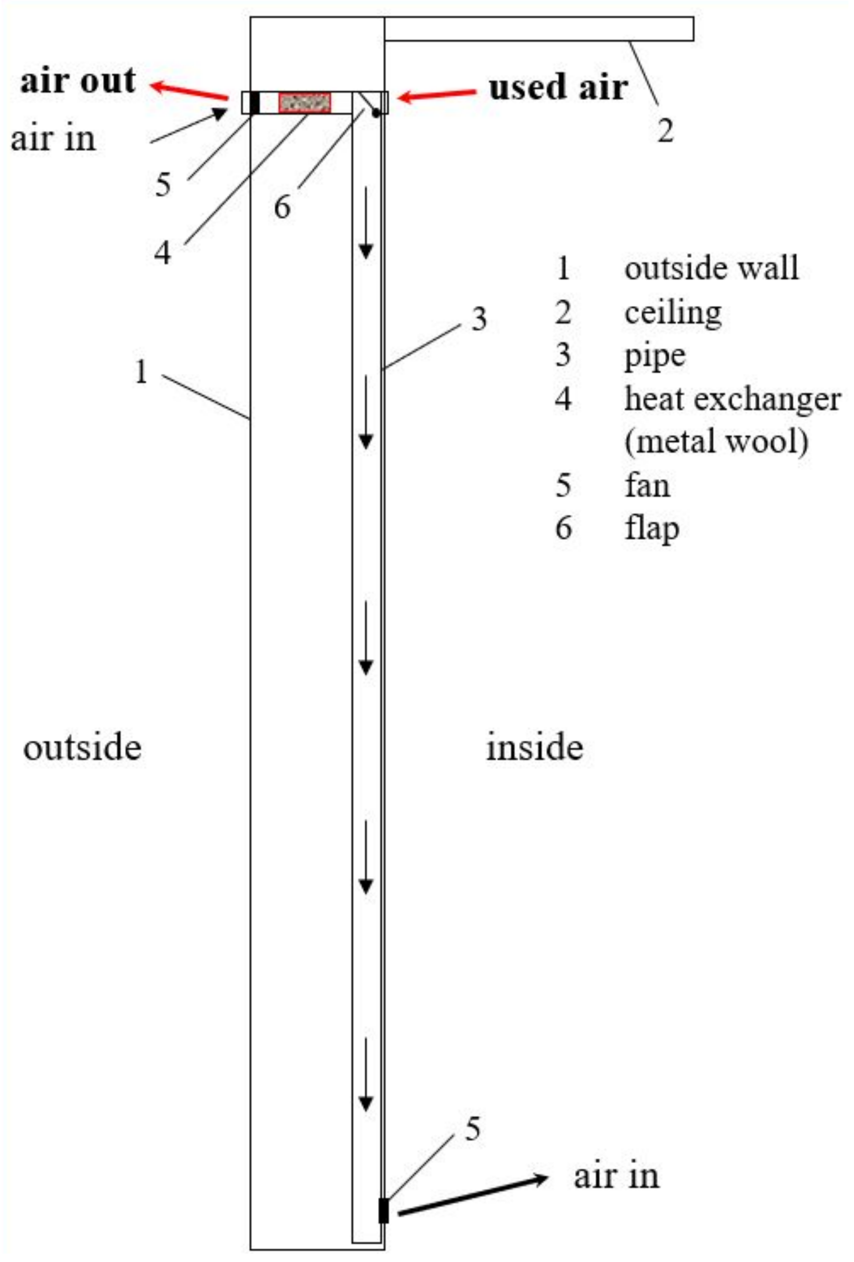
- the available water in developing countries is dirty. The Gravel system filters and purifies water in a natural way.
- the roof to storage connection avoids rainwater getting in contact with dirt on the ground and contaminats in the first place. Such a rainwater management system works best for buildings on a slope. The water outlet is then on the downward facing side of the building.



example: sand dam with tab on the lower side

heat recovery

- ventilation with heat recovery (in every room) should always be part of a Smart home because it is so cheap and efficient. It can cut the heating requirment in half.
- used air can also be discharged into a hollow slab above. This way the slab of the appartment above is heated and the used air will exit the building void of energy.
- heat recovery from used water and warm rain water has to be an integral piece of a Smart home, too. The Gravel system provides a platform to integrate all of these best practice technologies.



optimisation

- the energy storage capacity of the soil is 3x higher than that of the gravel. If the soil was wetter it might be 5.5x more.
- the system should manage the soil at maximum moisture. This would also increase the speed of energy distribution and the extend into the ground. The increase of moisture, if necessary, would be done with the condensate.

optimisation

- in case the ground gets to hot and the system looses the cooling capacity, cold air at night runs through the gravel and afterwards to the outside (not rooms). This way the gravel and ground can be cooled down. It is called Regenerative ventilation.
- as example for the choice of stones the mineral Zeolite is intersting. Zeolitic systems reach energy densities up to 15x higher than gravel and allow for seasonal storage with almost no heat loss (their price is 30x higher than gravel). Another example is salt-hydrate (phase-change-material)
- air vents in appartents should be equipped with fans so that the air-stream can be enhanced when it is necessary or of benefit. One case is pets alone at home. The temperature in the apartment should be dialed down as this is healthier for most pets. The air-flow based on the stack effect might then get to weak. The same applies for a person working out and not wanting to open the window.

highrises

- air intake for highrises, often with glass façade, would not be on ground level, but behind the façade.
- solutions for the heat transport many levels down to the Gravel system are possible. One is a mixer in which used warm air, after being heated behind the façade, runs through a shower of used cold water from designated cold-water bathroom sinks. The air leaves the building with reduced temperature after that and the heated water flows down into a heat-exchanger connected to the Gravel system (this solution is almost the opposite of Greywater recycling in air-conditioning).
- afterwards the water is released to the sewer, the on-site Greywater treatment, the reuse for flushing of toilets, or irrigation of plants outside.

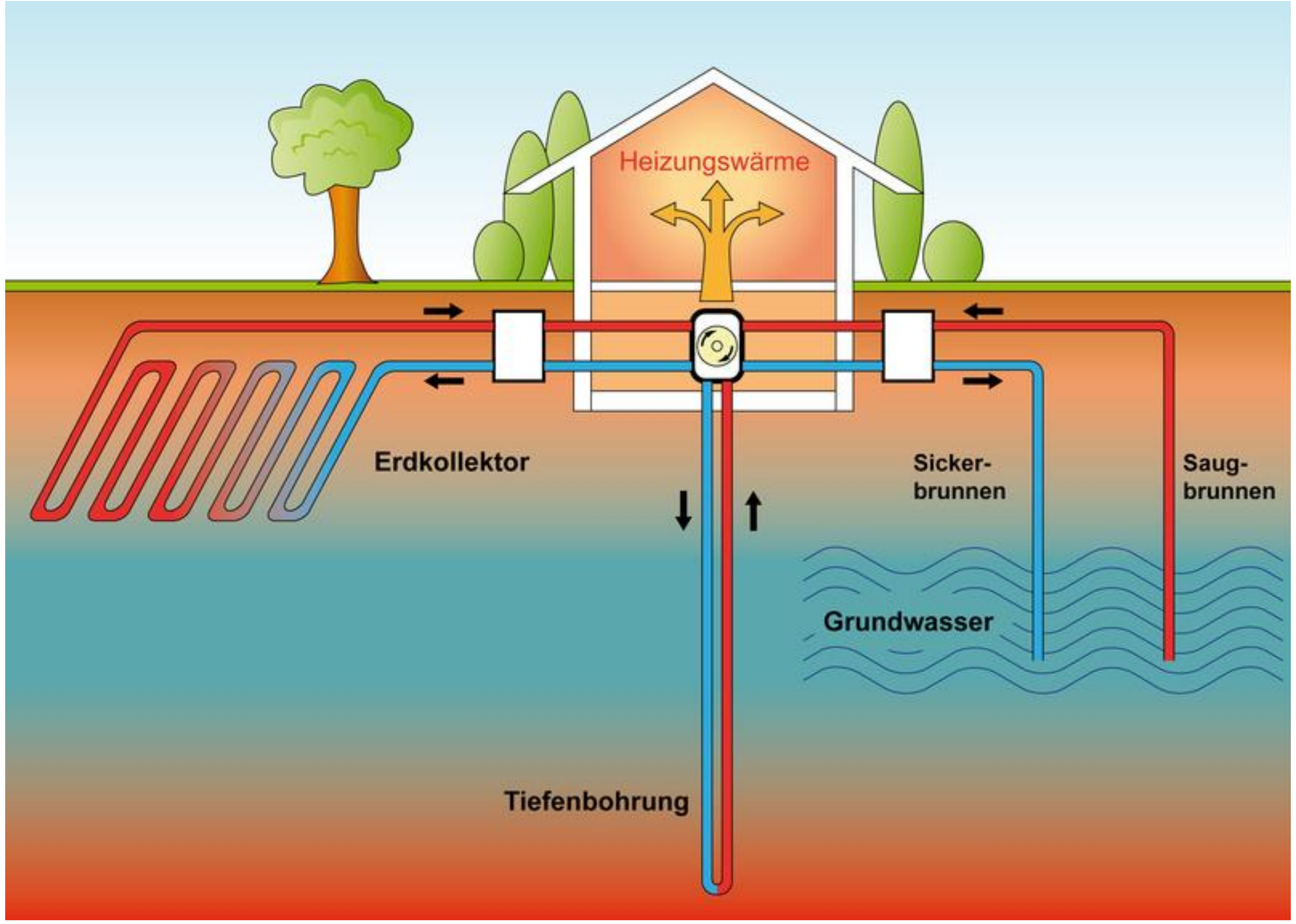
precedents

- The only examples for versions of a gravel storage built are greenhouses in Germany and the US. They are all very different from the proposed system in this presentation.

airchannels and gravelbeds, Rogmans

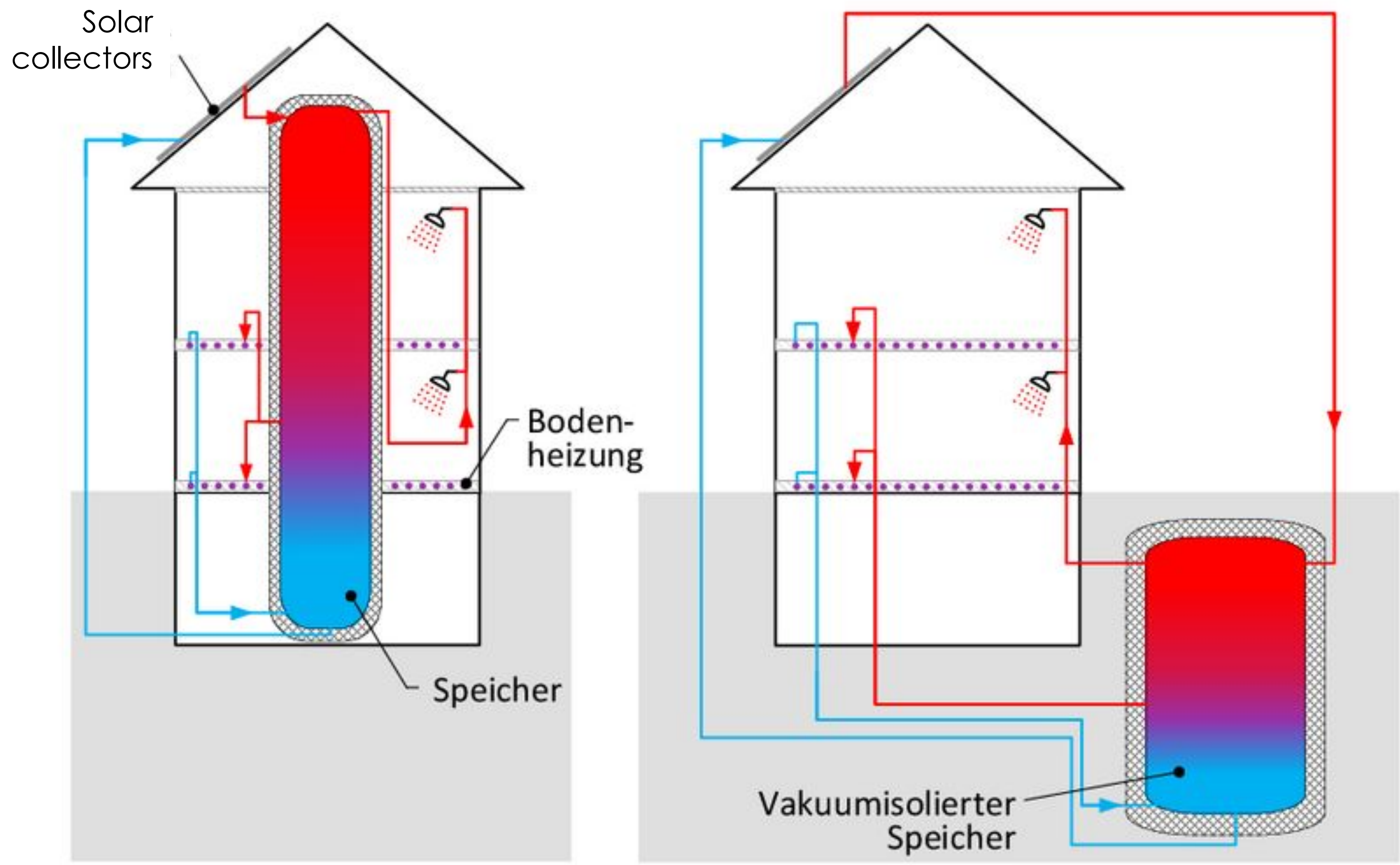
comparables

only Geothermal energy
less energy available, requires piping, electricity and heatpump



comparables

Solar thermal energy and water storage
requires expensive water tank and solar collectors, piping, pumps and electricity



construction details

- the system is so deep that roots do not reach it. This is one reason why no concrete walls are necessary.
- in addtion to the gravel channels there can be a gravel layer under the entire footprint of the house for quicker heat distribution into the soil (vertically). This layer can be thin.
- the gravel is placed in 20cm layers. Coarse gravel in the center and smaller gravel to the outside. Sand is poured on the border afterwards to constitude a wall. This way the soil can not fall into the gravel channel even if it undergoes freezing/thawing cycles. No mice can enter if built this way. This is better than the common use of a geotextile.
- only a small size-range of gravel stones can be used so that empty spaces between the stones remain.
- Radon is blocked by a pondfoil under the system.
- there must be a protection against cold rain events after summer which would remove the energy from the storage.

side effects

- enough of the Gravel system reduces the urban heat island effect
- it cleans the urban air around a building because air released from appartments without occupants is filtered from pollutents but not even higher in CO_2.

publications

„Aufbau, Funktion und Betriebserfahrungen mit Luftdurchströmten Schotterschüttungen“
Prof. Dr.-ing. Mario Reichel

„Exergetic and economical optimization of seasonal thermal energy storage systems“
Swiss Federal Office of Energy

„10 Jahre Solarenergieforschung am Institut für Technik in Gartenbaund Landwirtschaft der Universität Hannover“ Christian von Zabeltit

„Rock bed storage inside greenhouses“ Bredenbeck, Institute for Horticultural Engineering

„A study on the solar energy storing rock-bed to heat a polyethylene tunnel type“ greenhouse” Akdeniz University, Faculty of Agriculture

„Roadmap oberflächennahe Geothermie“ Fraunhofer-Einrichtung für Energieinfrastrukturen und Geothermie IEG

„ LowEx-Verbundforschung Luftdurchströmter Schotterspeicher“ Westsächsische Hochschule Zwickau

„Zeolite Heat Storage: *Key Parameters from Experimental Results“*

„ Assessment and reform of greywater reuse policies and practice: a case study from Sharjah, United Arab Emirates“ Sharjah University (Grey water recycling in cooling towers of air-conditioning systems)

further research

- models that charge with warm water (possible with sand)

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