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# Heating & Cooling with Geothermal Energy

## Heat Management in an Experimental Holistic Energy Grid

Holbein B., Isele J., Spatafora L., Hagenmeyer V.

Institute for Applied Computer Science (IAI), Karlsruhe Institute of Technology (KIT),
Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen

benedict.holbein@kit.edu

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## ABSTRACT

At KIT 16.75 million EUR are spend for infrastructure in order to establish the so-called “Energy Lab 2.0”. Within this “Energy Lab 2.0”, simulations and realistic experiments on energy grids are investigated, including renewables, power-to-heat solutions, storages and smart information and communication technologies. The Institute for Applied Computer Science (IAI) is mainly responsible for a Smart Energy System and Control Centre (SEnSSiCC) including an experimentation field (Smart Energy System Control Laboratory). This experimentation field on a smaller scale comprising all relevant components shall deliver data for the simulation of complete electricity and heat grids.

1. In this context and in favor of a scientific benefit analogies e.g. thermodynamics of Carnot process, heat transport processes, thermal properties of substances, heat storage etc. between two ongoing research activities at IAI are identified and applied. Besides the electricity, heat management is a key element in the reflections about the Energy Lab 2.0 at the IAI. As infrastructure for the experiments several consumption houses, a test hall and different producers and consumers are planned. Especially how geothermal low enthalpy systems can be used to support the grid through compensation of failures and by smoothing the energy balance is an interesting issue. Regarding the overall situation, the general features of geothermal energy as a base-load capable renewable energy is taken into account. For the heat management and possible air conditioning demands the direct use of geothermal heat in combination with absorption and compression heat pumps is investigated. Besides the usual living room case, special applications such as cooling of power electronic components and server rooms are further regarded scenarios.
2. Though the potential of geothermal energy as part of the energy system is undoubted, its exploitation is still a difficult topic in terms of acceptance and economic efficiency. That is why the ZWERG project at the KIT is concerned with a complementary system platform for the development of down-hole tools for investigation, sampling and repair. One basic problem on which technical solutions must be established is the combination of high ambient temperatures in geothermal wells and the usage of electronics with high variety and performance. The usability of standard electronics, enabled by active cooling would be a great advantage for this problem, hence down-hole cooling systems is a priority development target.

## 1. INTRODUCTION

Reliable energy supply is one of the major tasks for the future which has to be challenged by science and technology. Considering increasing energy demand and increasing requirements in terms of ecology and climate factors, only holistic concepts can generate satisfying solutions. Hence Geothermal Energy is supposed to play an important role in the energy grid of the future.

In Germany an advancement of the energy system is already acute, since the departure from nuclear and fossil energy sources is actually happening, including an intense expansion of renewable energies. The stabilization of the power grid is a complex task, not least because of the fluctuating production of important amounts of wind and solar energy. Therefore, among others the Karlsruhe Institute of Technology (KIT) has the mission to develop solutions for the stable power grid of the future.

The different roles geothermal energy can play in the future energy grid, are part of the investigation at the KIT, within the projects Energy Lab 2.0 and ZWERG.

Shallow geothermal energy for the heating of buildings is an interesting element within the investigation of heat networks. On the other hand, the therefore used heat pumps are a challenge for the electricity grid, when many of them are booted up or powered down at the same time. This is one of the scenarios which shall be investigated using the infrastructure of Energy Lab 2.0.

Deep geothermal energy can be used for electricity production or large scale heat production e.g. for district heating. Because of its constant production rates and availability it is suitable as renewable base-load supplier and could therefore be a supporting factor for the grid stability of energy grids containing a great amount of renewable energy sources, which is the central topic of Energy Lab 2.0. But in order to increase the usage of deep geothermal energy it has to become more reliable and secure, which can only be realized with a suitable quality management. One requirement therefore, are specialized down-hole tools. However, their current availability is not adequate and their development is challenging and expensive due to the extreme constraints. Hence the development of suitable technical solutions for down-hole tools is a task for fundamental research as performed within the project ZWERG.

This paper shows how expertise in thermodynamic cycles and technical heat management can be applied in the named domains, with selected examples.

## 2. ENERGY LAB 2.0 AND HEAT MANAGEMENT

### 2.1 Holistic energy network

The major objective of the project Energy Lab 2.0 is the investigation of dynamics and stability matters within an energy grid including a high amount of renewable energy production, in order to find ways for a stable and sustainable energy system. When investigating possibilities of advanced, intelligent respectively smart grids the complexity of actual energy systems has to be taken into account. Instead of simple producer to consumer connection, various energy and communication connections backwards and between the different products electricity, heat and cold are regarded. **Figure 1** illustrates this holistic energy grid idea.

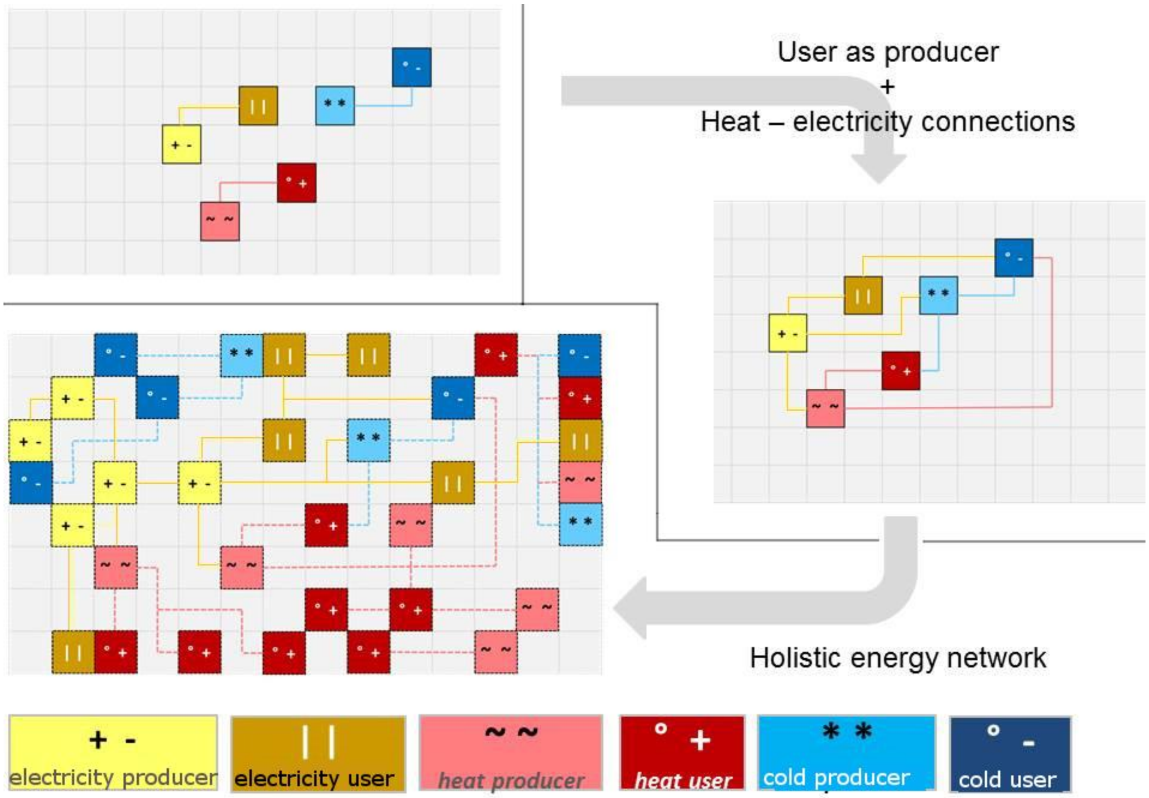
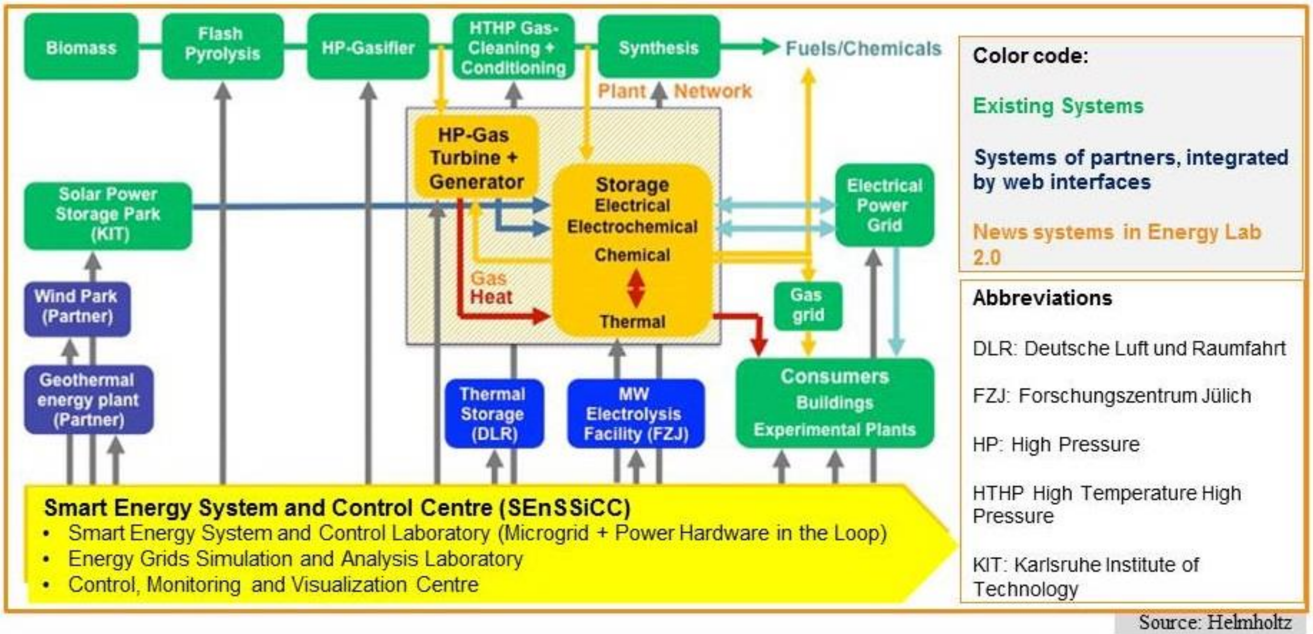


**Figure 1: Additional connections for a holistic consideration of energy grids**

A special element of the project approach is the combination of experiments, providing real data at a small scale and big-scale simulations. **Figure 2** gives an overview of the Smart Energy System and Control Centre (SEnSSiCC), the central part of the project, which also includes the Smart Energy System and Control Laboratory. This laboratory is supposed to deliver real data from energy grid hardware during operation. Electrical producers and consumers as well as heat producers and consumers shall be connected by a switchable matrix to provide maximal flexibility for the experiments [KIT 2015].



Source: Helmholtz

**Figure 2: Structure diagram of the SEnSSiCC in the Energy Lab 2.0 project**

## 2.2 Different approaches for heat and cold demand calculation

An important issue for a heat supply management is the calculation of the heating respectively cooling demands. No matter whether cooling or heating demand is regarded, there is a significant ratio between the base-load and the specific maximal loads of buildings, depending on the usage and weather factors. Hence a central question is which value is used for the design of the heating or cooling system. There are several possible approaches to describe the simplified problem whether to target the base-load or the maximal load for the estimation of the heating (cooling) device. One approach is to take the extreme case into account, which in case of cooling could be e.g. the hottest day during the past decade and to dimension the cooling system as big as necessary for a reliable air conditioning at this day. This of cause means that the system is way overdesigned for most of the days in the year. An alternative approach is to design a system for the base-load demand or an average value, anyway below the maximal demand case. This means that either a few days without sufficient cooling (heating) are accepted or any additional device for the peak load is installed. Since the actual comfort standard doesn´t include any lack of service and prices for standard heating devices relative to their size are low, usually the extreme case approach is applied, while for devices like heat pumps or absorption cooling machines modified considerations are suggested [BINE 2015]. They usually rely on surface (wall, floor…) heat exchange because therefore low supply temperatures are needed. That’s also why they are suitable for geothermal heat sources. Absorption cooling machines can also run with low input temperatures of under 70 °C [Holdmann 2005].

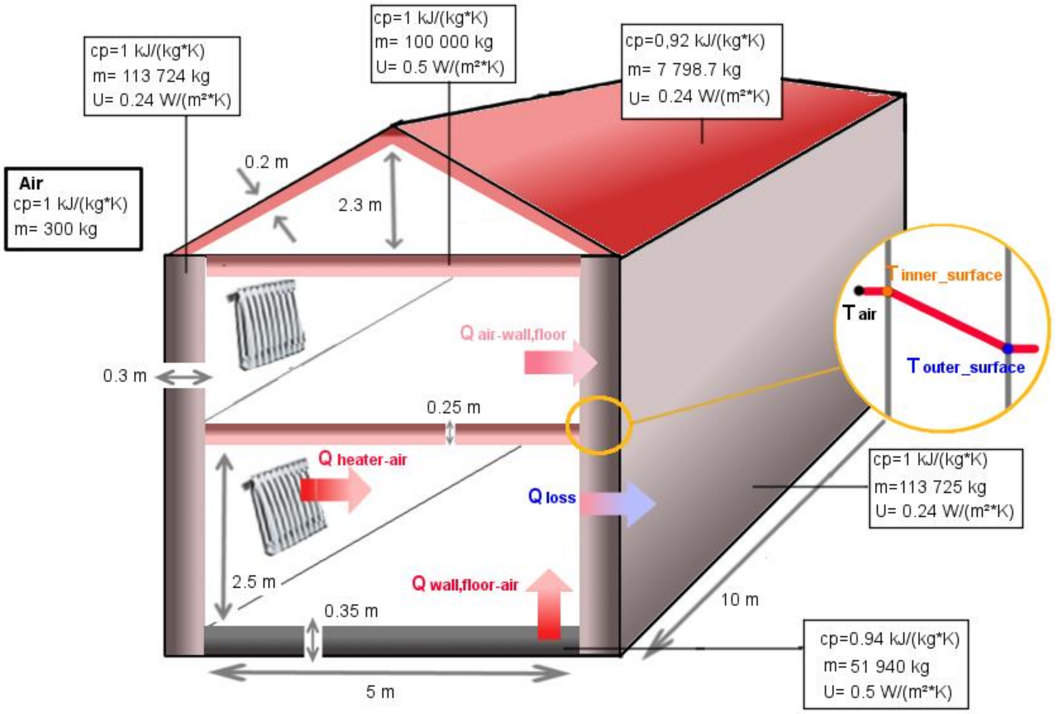


**Figure 3: Example house for the simplified heating simulation**

Using an example house (see figure 3) different heating systems based on surface heating and a direct air heating are investigated and compared. Surface heating systems are efficient for constant heat demand since they work with low supply temperatures. They are therefore well combinable with low temperature heat sources as shallow geothermal energy. The following simulation of an extreme case when a building is completely cooled shows three points:

- Surface heating isn´t suitable for demand peaks.
- There is a significant difference between the heating demand for maintaining a temperature and heating a building up.
- An approach for an efficient and reliable heating system is a combination of different heating systems.

In **figures 4&5** temperature profiles for the heating-up of a building are shown. For the simulation the building as illustrated in **figure 3** is used. Using the heat transfer values (U) of walls, roof and basement a heat transfer value of $U_{building}=0.28$ *W/(m^2*K)* is calculated as weighted average depending on the corresponding surface. The same is done for the building heat capacity, which is $cp_{building}=0.99$ *kJ/(kg*K)*. Regarding a start temperature of 5 °C with an outside temperature of -5 °C, the heating up profiles to the target temperature of 20 °C for air using wall-floor heat transfer (**figure 5**) or a radiator (**figure 4**) are compared.

It has to be pointed out that the focus for this simulation lays on the qualitative comparison of the heating up period of different heat systems, though the absolute values might not be exactly realistic. Nevertheless it can be clearly seen that wall and floor heating takes much more time to heat up the air inside the building. This is logical since the heat capacity of the walls, floors and roof are much bigger than the one of air. This shows that heat systems heating up the building through floor or wall surfaces which are the most efficient and therefore mostly used systems in combination with heat pumps (or cooling machines) aren´t suitable for this case.

The heat flows and temperatures for the cases wall-floor heating and direct air heating are calculated numerically with the time steps $n=1$ *min*. The maximal heating power: $dQ_{max.heating}/dt$ is set at 10 kW, with a target temperature $T_{target}=20$ *°C*. It is assumed that the temperature of the outer surface is constant and equal to the ambient temperature. The used surface related heat transfer coefficients $ks_i$ for the different heat flows are listed in **table 1**.

**Table 1: Surface related heat transfer coefficients**

| | | | |
|---|---|---|---|
| wall floor-air coefficient | $ks_{wall,floor-air}=\alpha_{surface-air}*A_{wall,floor}$ | 2000 | *W/K* |
| loss coefficient | $ks_{loss}=U_{building}*A_{outside}$ | 84.89 | *W/K* |
| heater air coefficient | $ks_{heater-air}=dQ_{max.heating}/dt/(T_{heater}-T_{target})$ | 250 | *W/K* |
| air –wall floor coefficient | $ks_{air-wall,floor}=\alpha_{surface-air}*A_{wall,floor}$ | 2000 | *W/K* |

For the calculation of the coefficients additionally the parameter $\alpha_{surface\text{-}air}=8\ W/(m^{\wedge}2*K)$, the inner and outer building surfaces $A_{wall,floor}$ and $A_{outside}$ as well as the supply temperature of the direct air heating system $T_{heater}=60\ °C$ are used. The following equations have been developed based on the fundamental heat transfer equations [VDI 2013] and model equations for dimensioning of house heating systems [Recknagel 2003].

The heat flows for the wall-floor heating are calculated as follows:

$$\dot{Q}_{heating,n} = \dot{Q}_{\max.heating} \;\; for \;\; T_{air,n-1} < T_{target} \;\; else \;\; \dot{Q}_{heating,n} = 0 \tag{1}$$

$$\dot{Q}_{wall,\,floor-air,n} = ks_{wall,\,floor-air} * (T_{innersurface,n-1} - T_{air,n-1}) \tag{2}$$

$$\dot{Q}_{loss,n} = ks_{loss} * (T_{innersurface,n-1} - T_{outersurface}) \tag{3}$$

$$\dot{Q}_{resulting,n} = \dot{Q}_{heating,n-1} - \dot{Q}_{loss,n-1} \tag{4}$$

The temperatures for the wall-floor heating are calculated using the heat capacities $cp_i$ and masses $m_i$ of building and air as follows:

$$T_{innersurface,n} = T_{innersurface,n-1} + \frac{(\dot{Q}_{heating,n-1} - \dot{Q}_{loss,n-1} - \dot{Q}_{wall.\,floor-air,n-1}) * 60s}{cp_{building} * m_{building}} \tag{5}$$

$$T_{air,n} = T_{air,n-1} + \frac{(\dot{Q}_{wall,\,floor-air,n-1} * 60s)}{cp_{air} * m_{air}} \tag{6}$$

The heat flows for the direct air heating are calculated as follows:

$$\begin{aligned} &\dot{Q}_{heater-air,n} = ks_{heater-air} * (T_{heater} - T_{air,n-1}) \\ &for \;\; \dot{Q}_{heater-air,n} < \dot{Q}_{\max.heating} \, else \;\; \dot{Q}_{heater-air,n} = \dot{Q}_{\max.heating} \\ &for \;\; T_{air,n-1} < T_{target} \;\; else \;\; \dot{Q}_{heater-air} = 0 \end{aligned} \tag{7}$$

$$\dot{Q}_{air-wall,\,floor,n} = ks_{air-wall,\,floor} * (T^{*}_{air,n-1} - T^{*}_{innersurface,n-1}) \tag{8}$$

$$\dot{Q}^{*}_{loss,n} = ks_{loss} * (T^{*}_{innersurface,n-1} - T_{outersurface}) \tag{9}$$

$$\dot{Q}^{*}_{resulting,n} = \dot{Q}_{heater-air,n-1} - \dot{Q}^{*}_{loss,n-1} \tag{10}$$

The temperatures for the direct air heating are calculated as follows:

$$T^{*}_{air,n} = T^{*}_{air,n-1} + \frac{(\dot{Q}_{heater-air,n-1} - \dot{Q}_{air-wall,\,floor,n-1}) * 60s}{cp_{air} * m_{air}} \tag{11}$$

$$T^{*}_{innersurface,n} = T^{*}_{innersurface,n-1} + \frac{(\dot{Q}_{air-wall,\,floor,n-1} - \dot{Q}^{*}_{loss,n-1} \;) * 60s}{cp_{building} * m_{building}} \tag{12}$$

As the simulated temperature profiles show the direct air heating is faster. In the regarded extreme case for a completely cooled down house, it takes around half the time to heat the air up at target temperature compared to the wall-floor (surface) heating. For comparison the heat demand for maintaining the room temperature once the target temperature is reached, in other words to equalize the heat losses is around 2 kW for the example house. This leads to a wide range for heating system dimensioning.

One possible, money saving approach which could encourage the expansion of renewable heat supply is to use low-dimensioned surface heating systems with low supply temperature (geothermal heat) which serve only for maintaining the room temperature. For the rare extreme cases when more heating power is needed (e.g. when a heating system isn´t running for several days) electric heating could be used. Heating grids with shared storages (analogous to the electricity grid) furthermore provide a better compensation of fluctuating demands and production and combination of different renewable heat sources as geothermal energy and thermal solar energy.

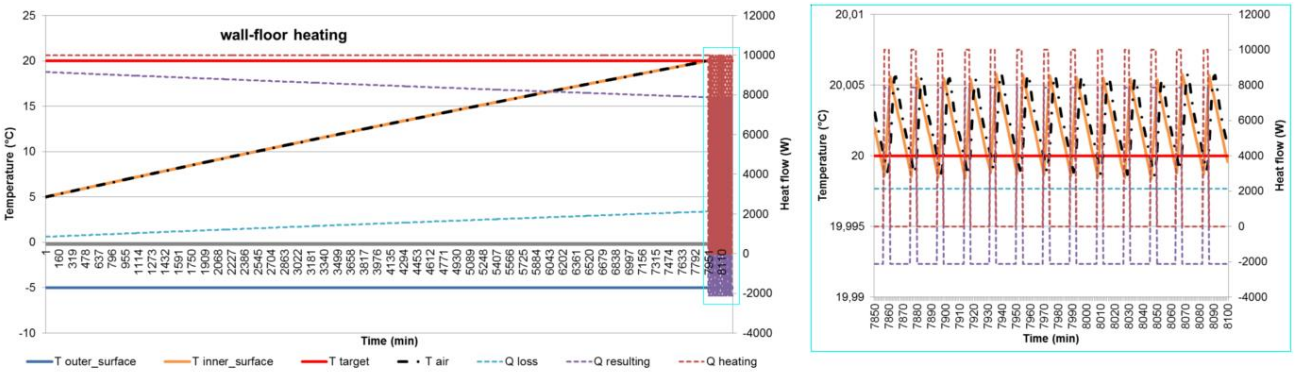


**Figure 4: Temperature profile for heating up with wall-floor heating**

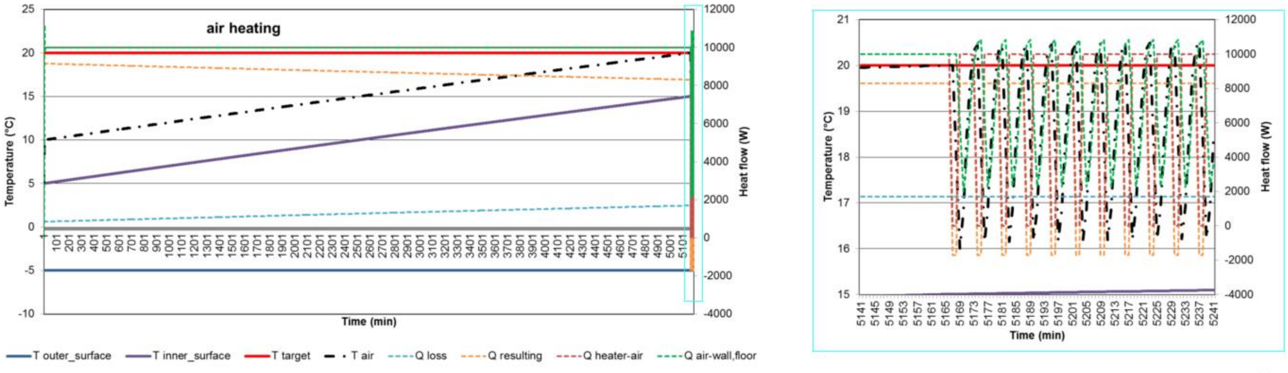


**Figure 5: Temperature profile for heating up with direct air heating**

The simulation is supposed to give a hint for a possible design approach for heating and cooling systems based on geothermal heat. It is obvious that in order to guarantee a full service either an additional heat source for demand peaks or any kind of storage is needed. For this case, concepts like a neighborhood network can be advantageous. By sharing single components of the heating system e.g. a storage or heat source bigger dimensions and an economically efficient design are supported.

### 2.3 Grid laboratory and neighborhood network

From an ecological point of view, the CO2 emissions as well as the primary energy consumption must be reduced, in order to realize a sustainable energy system for the future. However, the climate change already causes an increase of the cooling demand [Kreuter 2012]. Therefore heating and cooling based on renewables like solar and geothermal energy offer great advantages.

Heat supply and heat management are part of the investigations within Energy Lab 2.0. Therefore it´s planned to include a heat management network consisting of living buildings, heating systems and heat sources into the grid. They shall be connected in a kind of neighborhood network which provides further opportunities as single building systems. This is especially important when resources like geothermal heat, which provide limited flexibility and high investment costs, are used. As explained before heating or cooling systems using heat-pumps respectively cooling machines yield an efficient base-load supply using low supply temperatures and are therefore optimal for an integration of geothermal heat sources. The neighborhood network, shown in **figure 5** is supposed to support the compensation of demand peaks and the output efficiency using surplus heat. This could be a key for stable energy grids with a large amount of renewable energy.

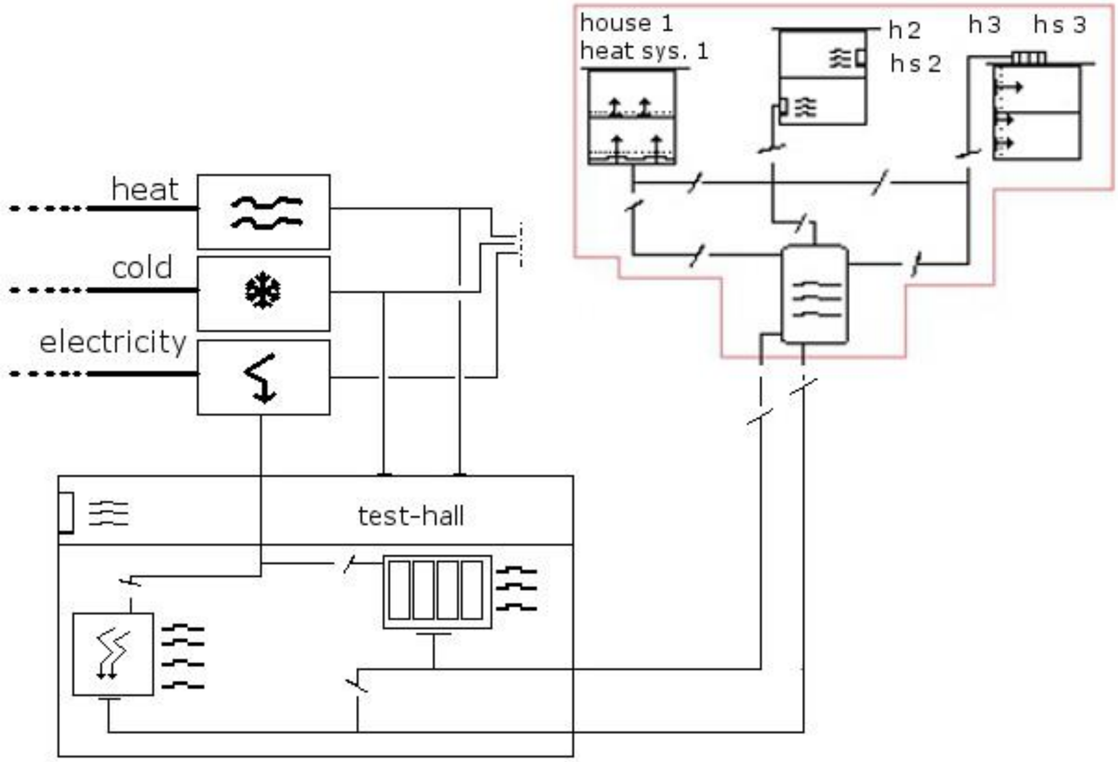


**Figure 6: System scheme of neighborhood network**

In a first approach it´s an advantage if heat and cold can be exchanged between different single houses and therefore use a common storage. Further steps would be the connection with the surplus heat of the electricity production grid level (energy laboratory) and district heating and cooling systems.

An illustration of the overall structure is given in **figure 6**, where the test hall with a generator set, the server room and an absorption cooling machine is shown as well as the houses of the neighborhood network, a geothermal heat source and additional renewable electricity producers.

From the electricity production side for the experiments there will be power-hardware-in-the-loop and generator sets in a power range of up to 1 MW. However this also means a temporary production of surplus heat or equivalent cooling demand. The servers for the simulation and visualization center will be installed in a server room in the test hall with a cooling demand of approximately 10 kW.

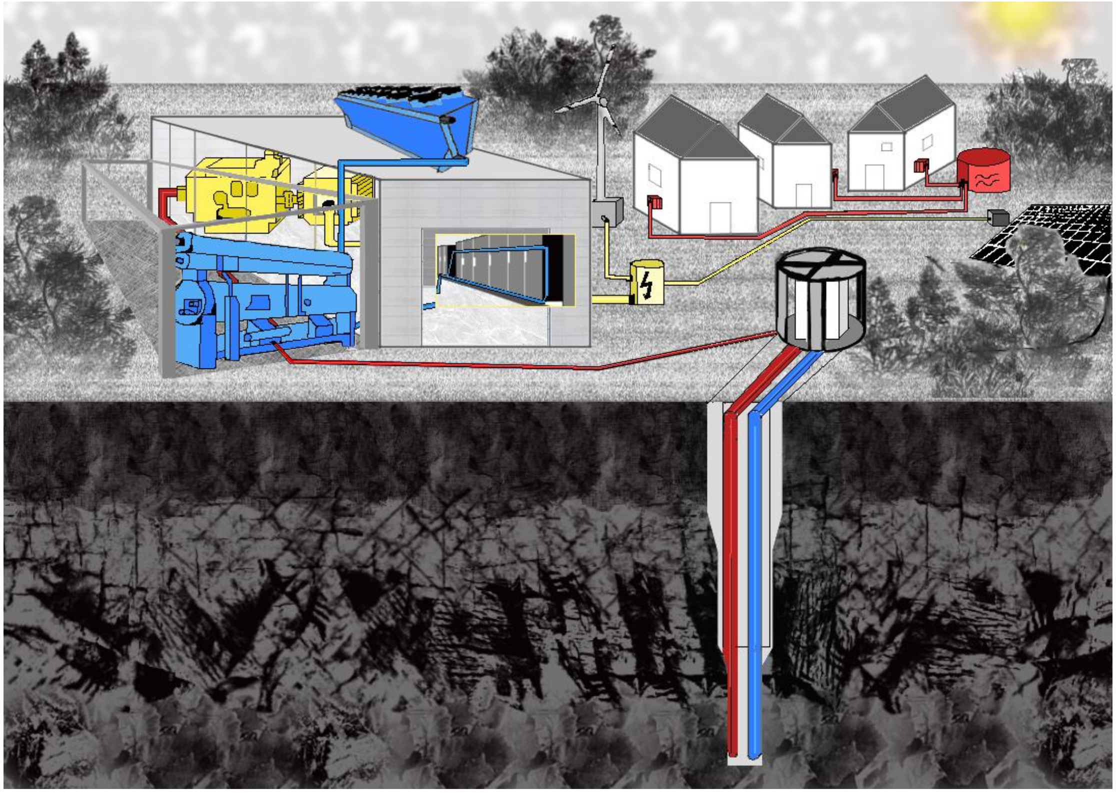


**Figure 7: Illustration of the overall energy system within Energy Lab 2.0**

## 3. COMPARISON OF COMPRESSION AND ABSORPTION COOLING

As implied in the Energy Lab system illustration (**figure 7**) an absorption cooling machine is a possibility to use surplus heat for component cooling or air conditioning. This is ecologically more efficient than to use compression cooling because nearly no electricity is necessary.

The system schemes of compression and absorption cooling machine are shown in **figure 8**.

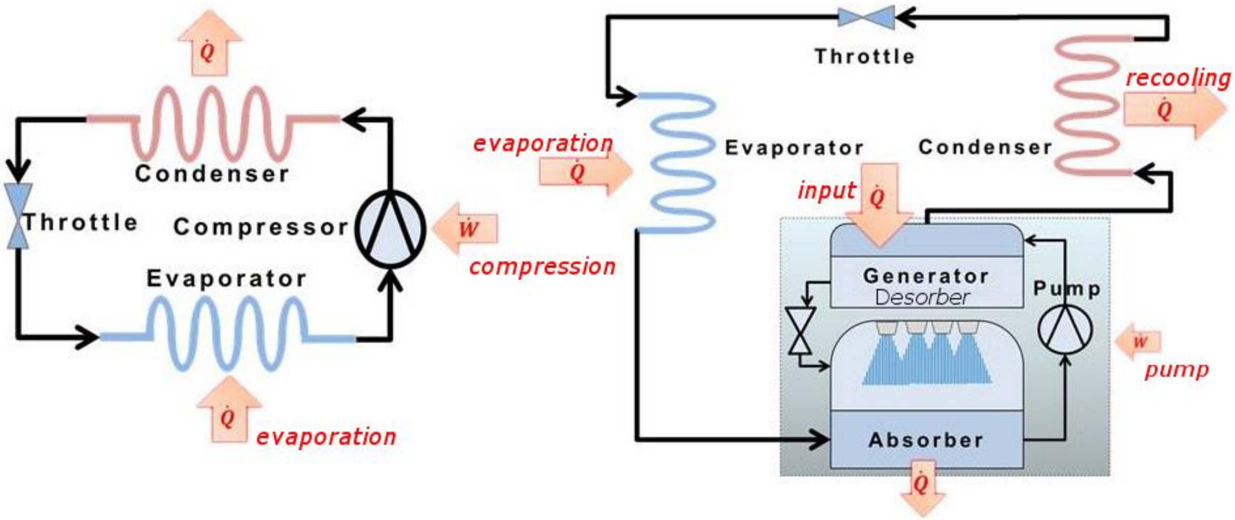


**Figure 8: System scheme of compression (left) and absorption cooling machine (right)**

The cooling effect in both systems is performed by the evaporation of a refrigerant in the evaporator, where heat is transferred from the cooled component or area. The difference is that the compression cooling machine consumes electrical power for the compression of the refrigerant steam for reaching a condensation temperature above ambient temperature. For absorption cooling heat is used as driving energy source. The refrigerant steam is absorbed by an absorbent which has a higher evaporation temperature. The solution is pumped at higher pressure level, with significantly lower energy consumption compared to the compression of gas. Afterwards heat is used for evaporating the dissolved refrigerant (desorption). In both cycles the refrigerant condenses while heat is transferred to the environment and expanses back to initial state in a throttle.

The cooling capacity in both cases depends on the refrigerant properties and the mass flow and is represented by the evaporation enthalpy. It can be calculated with the following equation (13) [VDI 2013]

$$\dot{Q}_{cooling} = \frac{dm}{dt} * \Delta h_{h,refrigerant} \qquad (13)$$

The mass flow *dm/d*t is controlled by the pump. The evaporation enthalpy *Δh* depends on the used refrigerant. For air conditioning around 20 °C compression cooling machines run with chlorofluorocarbons, for the absorption cooling process the substance couple lithium-bromide water is used, whereby water at low pressure works as refrigerant. The reachable efficiency of the cooling systems is defined with the energy efficiency ratio EER. For compression cooling the ratio between consumed electricity and cooling capacity as in equation (14) is used. For absorption cooling usually the thermal EER (equation 15a) instead of an electrical EER is calculated, using the heat input for desorption as in equation (15b) [VDI 2013].

$$EER_{compression} = \frac{\dot{Q}_{evaporation}}{\dot{W}_{compression}} \qquad (14)$$

$$EER_{absorption,electrical} = \frac{\dot{Q}_{evaporation}}{\dot{W}_{pump}} \qquad (15a) \qquad\qquad EER_{absorption,thermal} = \frac{\dot{Q}_{evaporation}}{\dot{Q}_{input}} \qquad (15b)$$

Usual values for compression cooling machines are around 1-3 and for absorption cooling machines between 0.5-0.7 thermal EER (electrical around 10). The maximal reachable efficiency is given by the Carnot efficiency, as calculated in equation (16). It is based on the temperature levels of evaporation and condensation (see **figure 9**).

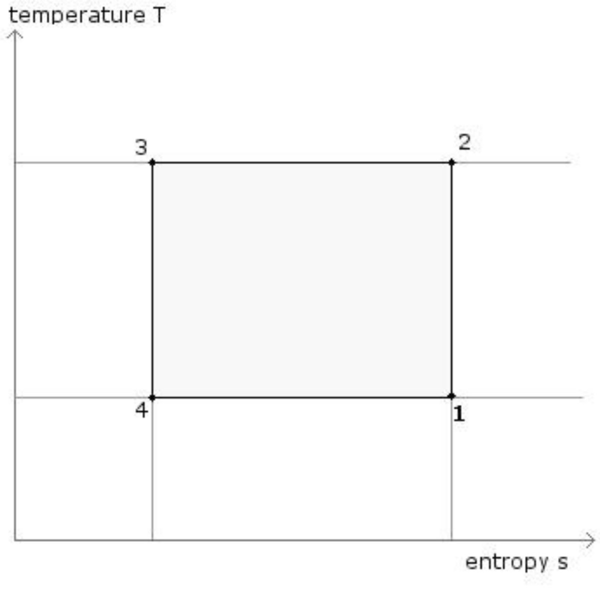


**Figure 9: Carnot process in temperature-entropy diagram**

The Carnot efficiency calculation is based on the ratio of exploited and input energy and can be simplified to a ratio of temperatures.

$$\eta_{Carnot} = \frac{dQ/dt_{cooling}}{dE/dt_{input}} = \frac{T_1 * (s_1 - s_4)}{(T_2 - T_1) * (s_1 - s_4)} = \frac{T_1}{T_2 - T_1} \qquad (16)$$

This makes clear, that the higher the ambient temperature is, the lower is the maximal effective process efficiency.

The advantage of absorption cooling is, as mentioned before, that it runs with heat instead of electricity which in many cases can be free or at least cheap surplus heat. Like this the higher investment costs compared to the more common compression cooling machines can be compensated by the operation costs within a certain period. In the case of the Energy Lab 2.0 the cooling demand of the server room is 10 kW. Since it is a research project with a runtime of three years and not credit based funding, the amortization is considered different from usual calculations. **Table 2** gives a cost comparison between a compression and an absorption cooling machine for a cooling capacity of 10 kW.

**Table 2: Cost comparison for 10 kW compression and absorption cooling**

| **Parameter** | **Absorption Cooling Machine** | **Compression Cooling Machine** |
|---|---|---|
| cooling capacity (kW) | 10 | 10 |
| investment (€) | 22.950 | 5.050 |
| full load hours (h) | 8.760 | 8.760 |
| annual operation costs<br>*(constant electricity price)* (€) | 1.649 | 5.218 |
| annual operation costs<br>*(increasing electricity price)* (€) | 1.887 | 6.365 |
| **1a sum** | 24.837 | 11.415 |
| compared amortization **3a** | **28.611** | **24.145** |

As can be seen the investment for absorption cooling machines are significantly higher as for compression cooling machines but compression cooling machines produce higher operation costs due to their electricity demand. The difference in operation costs is even higher if an increasing electricity price is assumed (as it is the case in Europe). Nevertheless the amortization for the regarded system size takes more than three years. After six years (constant electricity price) with this example the total costs for absorption cooling with 32.844 € would be lower than the costs of 36.358 € for compression cooling.

One disadvantage of absorption cooling machines is the limitation of cooling capacity depending on the ambient temperature. As shows **figure 10** the theoretical efficiency decreases with increasing condensation temperatures. For fulfilling the process the condensation has to be above the re-cooling temperature, which is usually given by the ambient temperature. This leads to the situation, that air conditioning systems show the lowest performance when they are needed most – when the ambient temperatures are high.

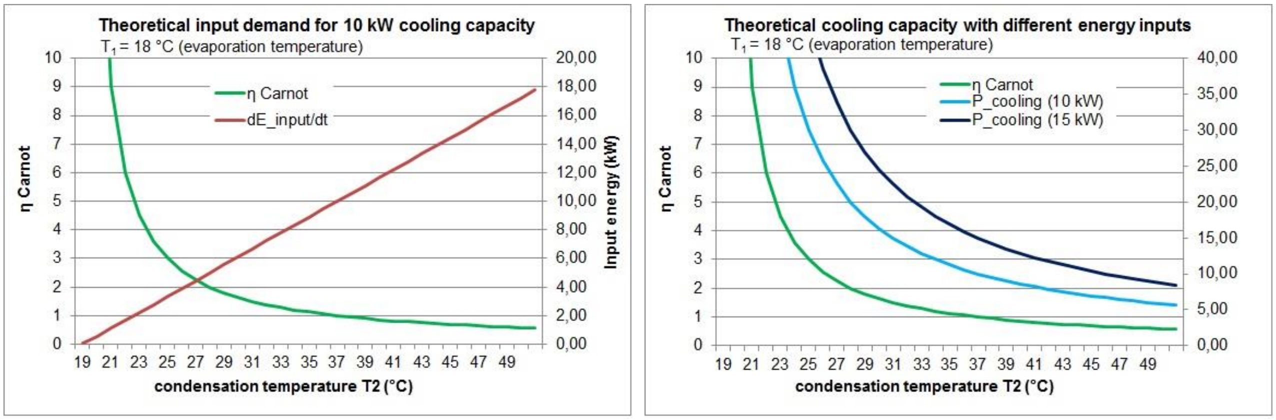


**Figure 10: Cooling capacity and EER of absorption cooling machine, depending on re-cooling temperature**

The performance of actual absorption chillers goes strongly down at ambient temperatures above 30 °C [Clausen 2013]. For reaching the required cooling capacity at higher ambient temperatures the condensation temperature has to be increased. In case of compression cooling this can be done relatively easy by increasing the compression pressure. For absorption cooling the desorption temperature has to be increased. However, this is limited since it depends on the available heat source, thus any source separated adjustment isn´t possible [Ziegler 2013]. Additionally the usable desorption temperature is limited by the used substance couple, because the refrigerant is desorbed thermally via evaporation, while the absorbent must stay in liquid phase.

## 4. SPECIAL COOLING DEMAND FOR GEOTHERMAL DOWN-HOLE OPERATIONS

### 4.1 Quality management for competitive geothermal energy

Another application for cooling systems related to geothermal heat are down-hole operations in deep geothermal wells. Geothermal energy could be a valuable element in a sustainable energy grid of the future because it is a base-load capable renewable energy source and can provide heat and electricity.

Currently the worldwide usage of geothermal energy stays way behind its potential. One of the reasons is the investment risks, due to high costs and the risk of insufficient production. In some regions, especially in Germany there is also a public resistance against the technology because of past projects causing private property damages. The public fear and the insufficient production are linked to technical problems which have to do with the limited possibility of down-hole interventions, because there are no available and suitable down-hole tools especially for deep and hot boreholes. But in order to make geothermal energy production more efficient in competition with fossil energy production using coal or gas, high temperatures are necessary.

To overcome this discrepancy a better quality management for geothermal projects is necessary, which can only be provided with a reliable quality management. Therefore suitable and available tools for investigation, measurement and interaction such as repair and sample recovery operations are necessary. Of course the operation conditions in deep geothermal boreholes are challenging. Depending on the region, temperatures over 300 °C and pressures of many hundred bars as well as highly corrosive thermal water represent the environment. Additionally in deep boreholes a strongly limited space of approximately 8 ½ inch in diameter is found. Therefore the development of down-hole tools for these constraints is a challenge which has to be supported scientifically.

This is why the Karlsruhe Institute of Technology is engaged in research activities to prepare an improved quality management based on suitable down-hole tools for geothermal energy and thereby support the technology to take a central role in the energy grid.

### 4.2 ZWERG platform and electronics cooling approach

The ZWERG system platform is an approach to design the development process of down-hole tools for extreme constraints in a time- and money saving way. It is based on the system platform idea where a standardization of basic modules is performed in order to reuse them in a modular way in various applications. Examples for possible operations currently regarded are video-inspection, sample recovery and repair as shown in **figure 11**.

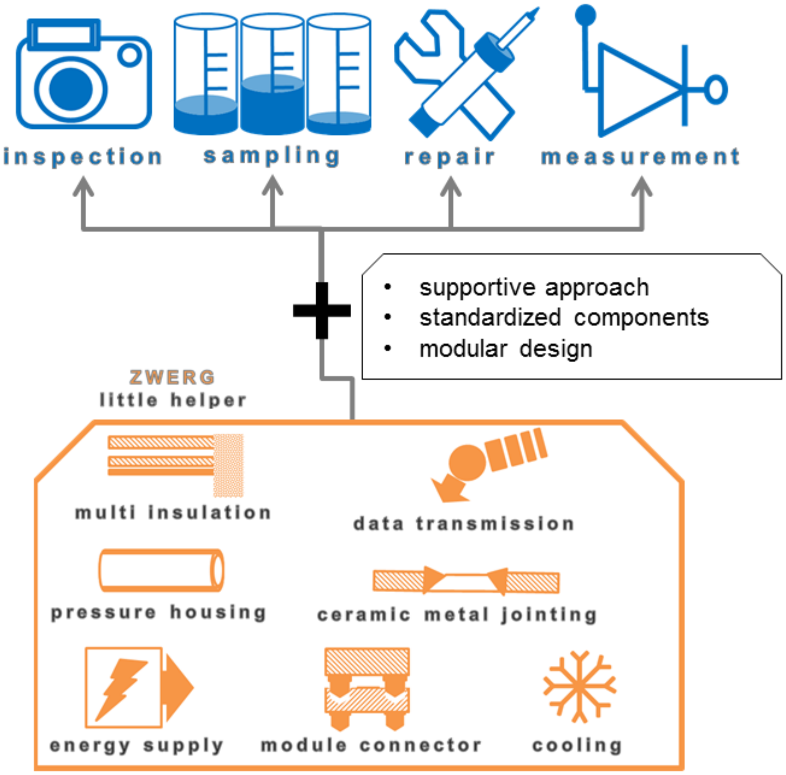


**Figure 11: Standardized modules and components and possible applications of the ZWERG platform**

Any complex operation will require a certain amount of electronics for control of down-hole devices, for data recovery and processing and for the communication with the surface. Surely there are high temperature electronics empowering some simpler operations for measurement and logging purposes but besides their high costs the range of available components for temperatures above 200 °C is limited. Anyway regarding the vision of complex operations, like repair of casings, real-time video-inspection or longtime logging with down-hole data processing in boreholes with temperature up to over 300 °C which would mark an important step towards a better understanding and controllability of the down-hole processes and therefore towards a functional quality management in geothermal energy project, a solution for continuous cooling is necessary in order to allow the usage of the complete range of standard electronic components and systems. For operations at ambient temperatures over 300 °C such a cooling option is required even if high temperature electronics are used. This is also true for so called measurement while drilling and directional drilling intends which are supposed to improve the drilling performance e.g. by providing possibilities to target hot springs. For an intelligent drilling system an electronic system with sufficient performance is necessary. At the same time the temperature load during drilling process for included components in the drill string can be very high.

Cooling methods play an important role in the ZWERG platform. Temporary cooling options as well as ways of timely unlimited cooling are part of the current investigations. Solutions are designed following the platform idea in a modular way. For continuous cooling in high temperature environments a down-hole cooling machine is being developed. For the realization of the system which is based on the long known cooling machine principle and commonly used in refrigerators and air conditioning systems, the special requirements caused by the constraints for borehole operations require a fundamental research on materials for seals, usable substances as refrigerants, investigation of thermodynamic sub-processes and an advanced embodiment design of system components. These are expensive tasks but once the functionality is achieved, the cooling machine will serve as basic module for many devices in the ZWERG platform [Holbein 2015].

**Figure 12** shows the investigated thermodynamic process which shall allow long-time cooling at ambient temperatures of up to 350 °C. Through two stages using different refrigerants and a connecting heat-exchanger between stage 1 and 2, the heat from the cooled area taken below 70 °C is transformed two times until refrigerant 2 condenses at 365 °C transferring heat to the surrounding.

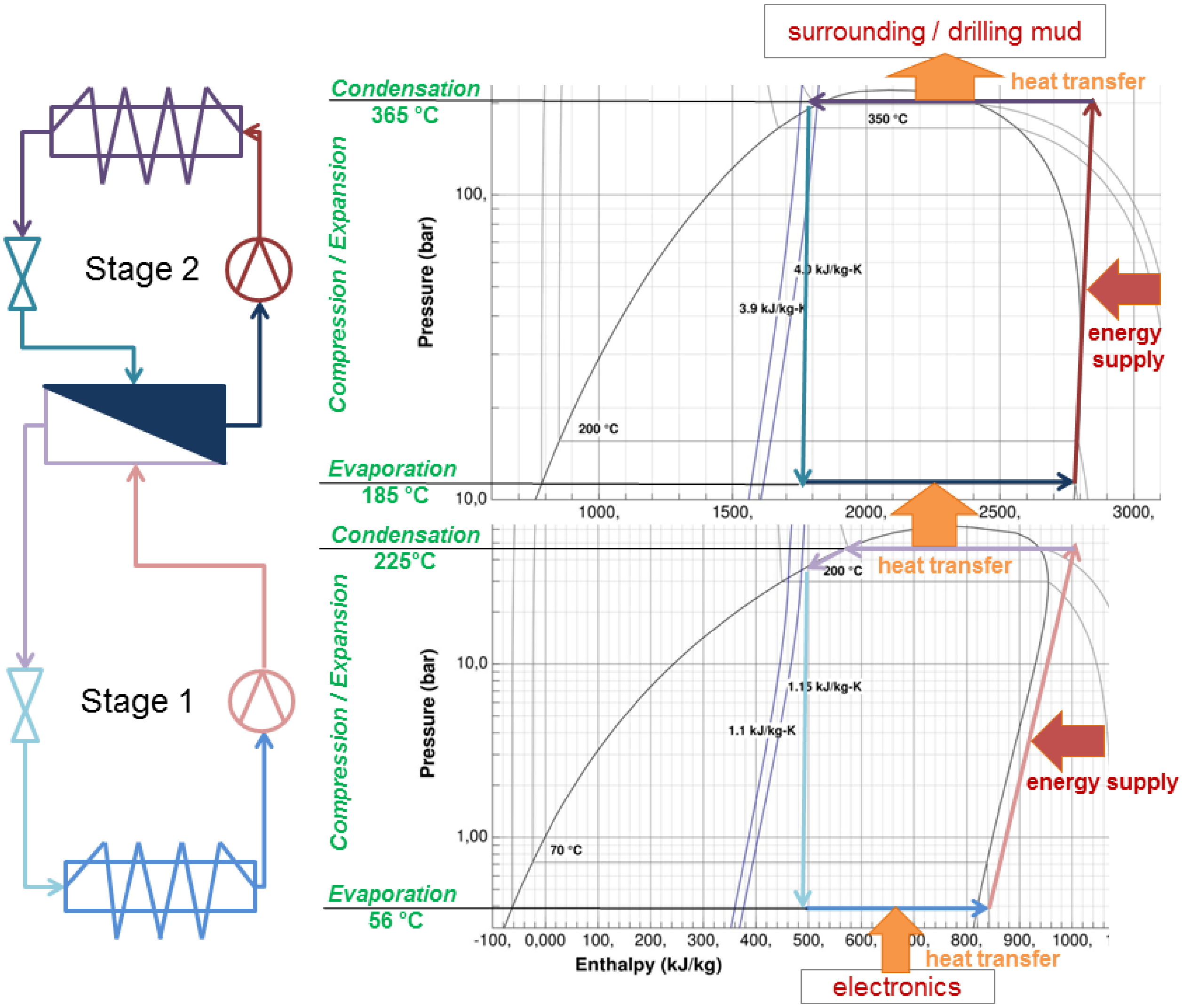


**Figure 12: Concept for down-hole electronic cooling at 350 °C using a two-stage cooling machine**

As refrigerant 1 the substances ethanol, acetone, 1.1-dichlorethane or mixtures are suitable. For the 2nd stage water promises the best performance. The sketched system contains an evaporator in the cooled area, a compressor for stage 1, a two-flow heat exchanger which serves as condenser for stage 1 and evaporator for stage 2, a condenser for stage two performing the heat transfer to the surrounding, a throttle component of stage 2 and a throttle component of stage 1, realizing the pressure and temperature drop for the closing of the cycle.

## CONCLUSION

The preparation and implementation of a sustainable energy system for the future is the biggest task of today's society. The targets: secure supply, grid stability and CO2 emission reduction must be achieved in parallel and require besides consistent political decisions, innovative solutions based on fundamental research.

The two described tasks, the investigation of potentials, benefits and problems for geothermal energy within electricity and heat grids and the empowerment of reliable quality management for deep geothermal energy by specialized down-hole tools are pre-conditions for the inclusion of geothermal energy in the future energy mix. Additionally they are connected regarding the technical questions of investigated processes as heat transfer and phase change processes, temperature profiles and gradients and how they depend on used refrigerants and insulation in both directions, just to mention some examples. The similarities and differences of technical challenges within these topics shall therefore be identified and used.

Both presented projects, the Energy Lab 2.0 and ZWERG deliver a brick for the realization of the ambitious mission. The Energy Lab 2.0 provides important knowledge about energy grids and impulses for their optimization for renewable energy production. ZWERG supports the growth of geothermal energy as base-load capable renewable energy source by building the base for down-hole tool supply empowering a reliable quality management.

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