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LOW TEMPERATURE HEAT TO POWER COUPLER

Abstract.*_*The Purpose of the Study *is to substantiate the possibility of a real connection of thermal energy, where heat generates energy (electricity) for low temperatures (below 120 °C).* ***The Research Methodology:*** *Methods of analysis, modeling, description and generalization of the data of the studied problem of low temperature heat to power coupler.* ***The Scientific Novelty*** *lies in the fact that for the first time, technical extensions of the well-known steam technology have been investigated, which, in combination with the newly chosen environment, make possible the innovative implementation of the technology.* ***The Conclusion****. The method is able to provide large amounts of energy, free of charge and indefinitely, because the energy reservoir "Earth" provides energy indefinitely and 24 hours a day. Of course, the application of low-temperature combined heat and power is not limited to geothermal energy. Hot industrial exhaust gases can also be considered if the volume flow is sufficiently high. The grade of efficiency of the system is infinitely large, since the effort = 0. Remaining task: finding the right turbine. At least as a first approach, the pentanes appear to solve the problem of selecting a refrigerant for energy transfer. As far as the turbine or piston machine is concerned, a solution is being sought that can reasonably drive a generator with pressures of 5−12 bar, with the power ultimately being adjusted via the volume flow.*

Keywords*: thermal energy, low temperatures, steam technology, pentanes,volume flow.*

The Relevance of the Topic. The tried and tested method of using warmth / heat to drive machines and thus also electric machines works in such a way that a fluid (water) is caused to evaporate by heating it. The resulting steam pressure drives either a piston engine or a turbine, which generates mechanical power, i.e. develops power. This is how it worked in the good old steam engine, and this is how electricity generation works in nuclear power plants. Water now has the attitude of evaporating under normal pressure = 1 bar at 100 °C and thus developing the pressure that is needed to drive a turbine or a piston machine. When pressurized, higher boiling temperatures can also be reached. The boiling point is the temperature at which a fluid changes its physical state from "liquid" to "gaseous". This boiling point depends on the external pressure.

Against the background of global change in energy supply, it is of particular interest to develop efficient methods, especially for power generation.

The Formulation of the Problem. Renewable energies are often mentioned as an energy source, such as wind power and solar radiation. (Whereas these two examples are not actually "regenerative", but stochastically available: unpredictably the wind blows or not. The same with the sun.)

In this respect, such energy sources are at best suitable as an addition to network relief and to cover peak loads and also make an important contribution. The latter also applies to all types of pumped storage power plants. But: a reliable supply of the base load cannot be achieved with all these methods.

River hydroelectric power is a hybrid: it can serve as a base load supply if the constant flow of water is secured year-round. And tidal power plants on the coast would certainly also be a solution for base load supply if the tidal range is sufficiently large.

Only conventional power plants are suitable for reliably covering the base load in the supply far from the coast: gas and coal-fired power plants as well as nuclear power plants. What all of these have in common is that they have to be fueled, i.e. they require an energy source that is used up.

The search for innovative technologies for the production of stable electricity is a modern scientific problem and requires a thorough solution.

The Purpose of the Article is to describe the innovative technology of low temperature heat to power coupler.

The Presentation of the Topic. Only in countries like Iceland the global geostructure accommodates the situation so far that the near-surface earth temperatures are very high in some places. Water vapor escapes on the surface, sometimes at 120 °C, and at a depth of a few hundred meters one finds earth temperatures of well over 100 °C in these places. In this respect, it is easy for the Icelanders, for example, to use the earth's energy free of charge and, above all, constantly and endlessly; in other words, to use the good old water vapor technology and use it to operate steam turbines.

But they only cook with water and that boils / develops steam at 100 °C. For differentiation, this temperature limit of 100 °C is referred to as the high-temperature range in the context of this publication.

The known procedures are therefore heat-power couplings in the high-temperature range.

New development / invention: Low-temperature heat to power coupling. The new idea is now to use this basically simple technology in the low-temperature range; i.e. in the temperature range below 100 °C.

The technical innovation (progress, inventive height) consists in:

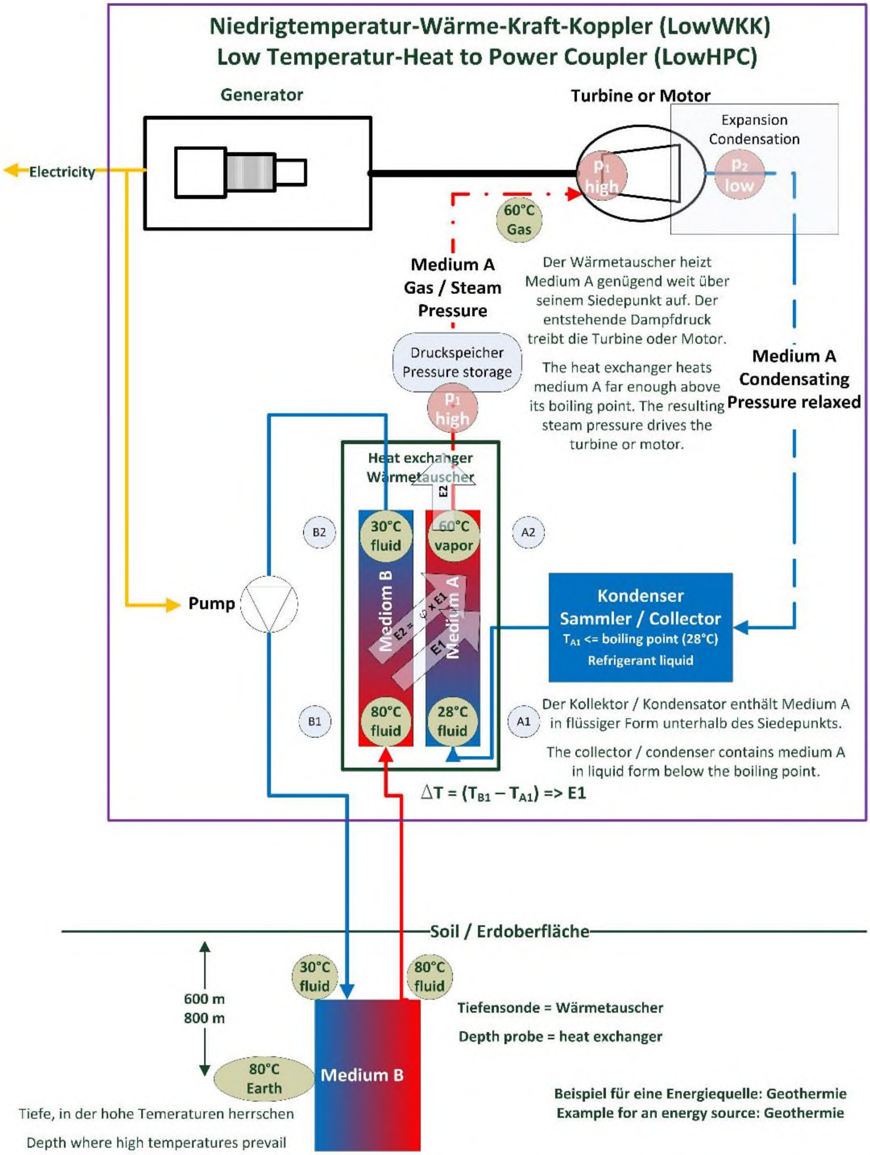
1. that instead of one working circuit, as has been the case since then, two working circuits are used: the first conveys the energy and the second delivers it to the mechanical unit (turbine or piston engine) as part of a Carnot cycle.

2. For the second working cycle (Carnot process), a refrigerant is used which meets the condition:

(Temperature $_{\text{source}}$ – T $_{\text{boiling point refrigerant}}$) >= 25 K approximately or at least fulfilled.

In practice, two media circuits are required as well as a heat exchanger and a fluid as one of the two media, which has its boiling point well below the temperature of the other medium:

Figure 1. Low Temperature-Heat to Power Coupler



Note: the temperatures shown are to be understood as examples, as is the type of heat exchanger shown. Depending on the need, other elements such as throttle valves, an expansion and condensation chamber after the turbine and the like can also be used.

Description:

The invention solves the problem of using relatively low source temperatures to generate power or electricity.

Two circuits are used for this, which exchange thermal energy from the ground. Medium B is always liquid and draws the heat from the source in the circuit. It can be water. Medium B flows through the heat exchanger and transfers its energy to medium A.

Medium A is a low-boiling fluid from the refrigerant class. It is crucial that the boiling point (boiling temperature) is far enough below the temperature that medium A brings with it from the source.

Medium A is heated above its boiling point and will accordingly vaporize or assume its gaseous state. The resulting pressure drives the turbine, whose shaft drives the generator.

So the refrigerant becomes the energy

$$E_1 = m_{H2O} \times c_{p\ H2O} \times (T_{H2O\ source} - T_{boiling\ point\ refrigerant})$$

supplied when medium B is water.

C_p is the specific heat capacity of the medium.

As it flows through the turbine, the pressure and temperature of medium A decrease. The design of the machine determines that complete condensation of the medium A only occurs after leaving the turbine.

Medium A, which has been cooled to below its boiling point, collects in the liquid aggregate state in the collection container. This is attached in such a way that the resulting column of liquid is sufficient to fill the heat exchanger to a sufficient level without the aid of a pump.

The system is started by starting the feed pump for medium B. A shut-off valve remains closed until the required operating pressure is reached.

Energy balance. The table below shows the energy balance for the nergy quantity 1 MWh:

Table 1. Energy in hot water

Specific heat capacity	H2O liquid	
Cp H2O	4,183	kJ/(kg*K)
	0,001162	kWh/(kg*K)

E = m * Cp * DT
m = V = E / (Cp * DT)

DT	25	K
E	1	kWh
Cp	0,001162	kWh/(kg*K)
V = m	34,42	L

DT	25	K
E	1000	kWh
	1	MWh
Cp	0,001162	kWh/(kg*K)
V = m	34.423,41	L
required flow rate	34,42	m^3

Example Beuren thermal bath		
extraction depth	600	m
water temperature source	48	°C
boiling point refrigerant	25	*C
DT	23	K
E	1000	kWh
	1	MWh
Cp	0,001162	kWh/(kg*K)
V = m	37.416,75	L
required flow rate	37,42	m^3

E is the energy transferred in the heat exchanger.
Heat exchanger + turbine have efficiencies.
The head of the pump = 0 m, only frictional resistance.

In order to generate 1 MWh of energy, with a temperature difference

DT = (source temperature – boiling point of refrigerant) = 25 K

approx. 35 m^3 of the source medium must be pumped. This is within reasonable limits, especially since no hydraulic height has to be pumped due to the U-tube principle.

If this amount of energy is related to a period of 1 hour, then the prerequisites for a power plant with an output of 1 MW have been created. To do this, V = 35 m^3 of the source medium must be pumped per hour; V. = 35 m^3/h.

Of course, some efficiency-related losses still have to be deducted here, but they also occur in comparable systems.

Result: The method is simple and consists of proven components. It is able to provide large amounts of energy, free of charge and indefinitely, because the energy reservoir “Earth” provides energy indefinitely and 24 hours a day.

What we need is a suitable refrigerant for the circulatory process of medium A. "Suitable" here means that the condition is met

$$\textbf{(Temperature}_{\text{medium B}} \textbf{ - boiling point}_{\text{medium A}}\textbf{) >= 25 K}$$

i.e. the selection of the refrigerant always depends on the temperature of the source. However: the higher the temperature of the source, the greater the energy yield will be.

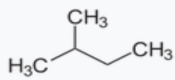
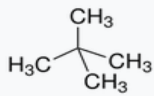
Of course, the application of low-temperature combined heat and power is not limited to geothermal energy. Hot industrial exhaust gases can also be considered if the volume flow is sufficiently high.

It is definitely conceivable to replace cooling towers with such systems.

Selection of a suitable refrigerant. We want to work in a working range from ambient temperature to, say, 85 °C source temperature. That would be an expected maximum value for the source temperature if geothermal energy is to be the energy source. At ambient temperature, the refrigerant should assume the liquid state without additional cooling. The boiling point of the coolant should therefore (in cooler regions) be above 25 °C.

You will find what you are looking for right away in the field of pentanes.

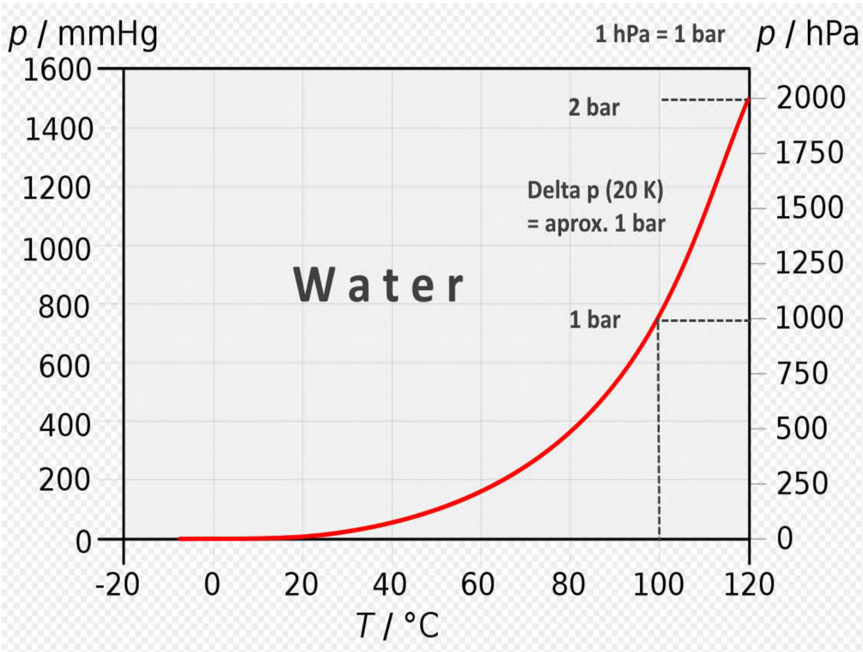
Table 2. Properties of the Pentanes

Eigenschaften der Pentane[1]			
Name	Pentan[2]	Isopentan[3]	Neopentan[4]
Andere Namen	Pentan (IUPAC)	2-Methylbutan	2,2-Dimethylpropan
Kältemittel	R-601	R-601a	R-601b
Strukturformel			
CAS-Nummer	109-66-0	78-78-4	463-82-1
PubChem	8003	6556	10041
Summenformel	C_5H_{12}		
Molare Masse	72,15 g·mol^{-1}		
Kurzbeschreibung	farblose Flüssigkeiten		farbloses Gas
Schmelzpunkt	−130 °C	−160 °C	−16,6 °C
Siedepunkt	36 °C	28 °C	9,5 °C
Dampfdruck (20 °C)	562 mbar	761 mbar	1456 mbar
Dampfdruck (30 °C)	815 mbar	1080 mbar	2100 mbar
Dampfdruck (50 °C)	1590 mbar	2042 mbar	3700 mbar
Dichte	0,63 g·cm^{-3}	0,62 g·cm^{-3}	0,6135 g·cm^{-3}
Löslichkeit in H_2O	39 mg·l^{-1}	50 mg·l^{-1}	33 mg·l^{-1}
Flammpunkt	−49 °C	−57 °C	<−7 °C
Heizwert	12,6 kWh·kg^{-1} oder 45,4 MJ·kg^{-1}		
Untere Explosionsgrenze (UEG)	1,1 Vol.-%	1,3 Vol.-%	1,3 Vol.-%
	33 g·m^{-3}	38 g·m^{-3}	40 g·m^{-3}
Obere Explosionsgrenze (OEG)	8,7 Vol.-%	7,6 Vol.-%	7,5 Vol.-%
	260 g·m^{-3}	230 g·m^{-3}	230 g·m^{-3}
Zündtemperatur	260 °C	420 °C	450 °C

It is immediately apparent that pentane R-601 and isopentane R-601a come into question because of the suitable boiling point, while neopentane R-601b is ruled out because the boiling point is too low.

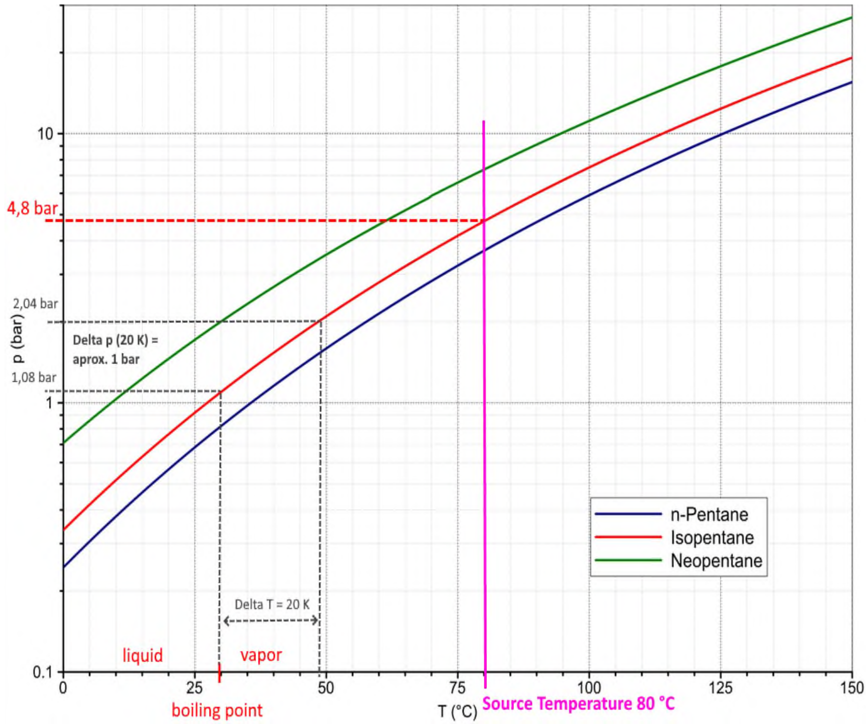
The pressure gradient **Dp (20 K) = aprox. 1 bar** shows up: when the temperature increases by 20 K above the boiling point, the vapor pressure has doubled from 1 bar to 2 bar. (isopentane). Interesting at this point is the comparison with water, which has been proven to be suitable for energy transfer:

Figure 2. Steam pressure water



A comparison with the vapor pressure curve of water also shows a pressure increase of 1 bar when the temperature rises by 20 K above the boiling point at 100 °C. One can now compare the vapor pressure curves of the pentanes:

Figure 3. Steam pressure Pentanes



One first notices that the vapor pressure curve for water tends to increase exponentially with increasing temperatures. However, it should be noted that Figure 4 is a logarithmic representation! In this respect, one might initially assume that the courses of the curves will be similar. In the case of the low-temperature application in question here, however, really high temperatures are not reached per se.

If one evaluates Figure 4 for isopentane in more detail, then for a source temperature T source = 80 °C one arrives at a pressure increase Dp of around 5 bar, calculated from the boiling point T boiling point = 28 °C.

This pressure, which is solely dependent on the source temperature, would now act on the blades of the turbine or on the pistons of the piston engine and, multiplied by the volume flow and some other factors, the machine output would result.

Application in geothermal energy (as an example). It is known that the temperature of the ground increases with increasing depth. The gradient is given as 35-40 K / 1000 m. Existing mines have a depth of up to 3000m. If you calculate with 35 K / 1000 m, this means that at a depth of 3000 m there is a temperature of 105 °C, if you consider the earth's surface with 0 °C. In this example we therefore have a source temperature of 105 °C. Isopentane has a boiling point of 28 °C. If you now insert these values into the already known calculation, you get:

Table 3. Energy and volume flow

Example Mine 3000m depth			
DT / 1000m		35	K
Lit.: 35-40K /1000m			
depth		3000	m
T in depth		105	°C
water temperature source	T_{source}	105	°C
boiling point refrigerant	$T_{boiling\ point\ refrigerant}$	28	*C
refrigerant: R-601a Isopentan			
DT	$T_{source} - T\ b_{oiling\ point\ refrigerant}$	77	K
E		1000	kWh
		1	MWh
Cp_{H2O}		0,001162	kWh/(kg*K)
V = m		11.176	L
required flow rate H2O		11,18	m^3

A look at Figure 4 shows that for T = 105 °C we already get a pressure of well over 10 bar. That should be enough to operate a turbine or a piston machine tailored to this application.

For comparison: hydroelectric turbines in hydroelectric power plants produce quite reasonable electrical output with a head of 12 m. Ultimately, however, a turbine is not driven by the head, but by the mechanical pressure on the blades, which is only 1.2 bar at a head of 12 m.

If we now enlarge the system by a factor of 100 and refer to one hour of time, then we get a power plant with an output of 100 MW:

Table 4. Energy and volume flow

Example Mine 3000m depth	Faktor 100	100 MW	related to 1 hour
DT	T source - T boiling point refrigerant	77	K
P = E / h		100000	kW
		100	MW
Cp H2O		0,001162	kWh/(kg*K)
V = m		1.117.643	L
required flow rate H2O		1.118	m^3/h
		18,63	m^3/min

For this we need a pumped volume flow of 18.63 m^3/min. That's not much, especially since we – it should be remembered - due to the U-tube principle we only have to overcome the flow resistance, but not have to pump 3000 up.

Exactly this consideration encourages to increase the plant again by a factor of 10 and we get a power plant with an output of 1 GW:

Table 5. Energy and volume flow

Example Mine 3000m depth	Faktor 1000	1 GW	related to 1 hour
DT	T source - T boiling point refrigerant	77	K
P = E / h		1000000	kW
		1000	MW
Cp H2O		0,001162	kWh/(kg*K)
V = m		11.176.431	L
required flow rate H2O		11.176	m^3/h
		186,27	m^3/min

Even pump capacities of 186 m^3/min are not a problem if the geodetic height to be overcome is = 0.

The earth energy supplies free and infinitely.

Again as a reminder and to avoid misunderstandings: P or E in the calculations does not mean the power or energy of "the water". The hot water only supplies the energy to the heat exchanger.

The refrigerant actually gets fed the energy;

E = m H2O x cp H2O x (T H2O source – T boiling point refrigerant)

This energy is passed to the turbine in the form of isopentane vapor (here in the example, minus small efficiency losses).

E leaving the heat exchanger can of course be expressed in the form of pressure x volume (flow).

For large volume flows, the lower heat exchanger is designed not just as a probe, but as a real heat exchanger with dimensions. But mine shafts with their existing cross section (10x x 10 m) and existing elevators are particularly suitable for this.

Total energy balance and efficiency. The useful energy of the plant calculated as:

$$\mathbf{E_{win} = E_{1} \times f_{Heat\ exchanger} \times f_{Turbine} \times f_{Generator} - E_{Pump}}$$

with

$$\mathbf{E_{1} = m_{H2O} \times c_{p\ H2O} \times (T_{H2O\ Source} \times f_{T} - T_{boiling\ point\ refrigerant})}$$

This equation applies when the boiling point is around ambient temperature. In real operation, there will always be deviations due to temperature fluctuations, etc. Thermodynamic systems always adapt to the current operating conditions

and

f Wärmetauscher	efficiency	Ca. 0,85
$f_{Generator}$	efficiency	Ca. 0,99
$f_{Turbine}$	efficiency	to be determined with the turbine manufacturer
f_T	temperature factor HE	Ca. 0,95 (cause heat exchanger)
m_{H2O}	mass or volume	of the circulated water
$c_{p\ H2O}$	Spez. heat capacity H2O	

E_{pump} is calculated from the hydraulic resistance and the volume flow. The hydraulic resistance is expressed as a pressure loss Dp and due to the series connection of the individual sections, the following applies:

$$\mathbf{Dp}_{\mathbf{total}} = \mathbf{Dp}_{\mathbf{Heatexchanger\ top}} + \mathbf{Dp}_{\mathbf{Heatexchanger\ bottom}} + \mathbf{2x\ Dp}_{\mathbf{Pipe\ lenght}}$$

Pressure loss due to geodetic head does not occur.

Now the energy expenditure has to be determined to calculate the overall efficiency. However: the necessary energy is provided by the earth itself. =>

The grade of efficiency of the system is infinitely large,
since the effort = 0.

Heat exchanger as evaporator, evaporator performance. The upper heat exchanger is of particular importance, as it also acts as an evaporator for the refrigerant. The table below quantifies the mass used and the evaporator performance for a pentane compared to water.

Table 6. Mass of refrigerant comparison

Mass of used Refrigerant			(in comparision to water)		Evaporation performance in heatexchanger	
$Dh_{v\ n\text{-}pentan}$	357	hJ/kg	0,10	kWh/kg		
$Dh_{v\ Water}$	2257	hJ/kg	0,63	kWh/kg		
$E = H = m\ x\ Dh_v$			$m = E / Dh_v$		/ 60 min	
E_2 (to store)	1.000	kWh	0,44	kg H2O	0,01	kg H2O/min
	1	MWh	2,80	kg n-Pentan	0,05	kg n-Pentan/min
	100.000	kWh	44	kg H2O	0,74	kg H2O/min
	100	MWh	280	kg n-Pentan	4,66	kg n-Pentan/min
	1.000.000	kWh	443	kg H2O	7,38	kg H2O/min
	1	GWh	2798	kg n-Pentan	46,63	kg n-Pentan/min

It turns out that water is the better energy carrier in terms of vaporization enthalpy. But in relation to the amounts of energy, the masses used and the necessary evaporator capacities for pentane are within tolerable limits.

Remaining task: finding the right turbine. At least as a first approach, the pentanes appear to solve the problem of selecting a refrigerant for energy transfer.

As far as the turbine or piston machine is concerned, a solution is being sought that can reasonably drive a generator with pressures of 5−12 bar, with the power ultimately being adjusted via the volume flow.

Renewable energies are often mentioned as an energy source, such as wind power and solar radiation. (Whereas these two examples are not actually "regenerative", but stochastically available: unpredictably the wind blows or not. The same with the sun.)

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Only conventional power plants are suitable for reliably covering the base load in the supply far from the coast: gas and coal-fired power plants as well as nuclear power plants. What all of these have in common is that they have to be fueled, i.e. they require an energy source that is used up.

Other technologies for producing electricity from heat. Other research approaches in the field of photoelectric and thermoelectric effects are known.

The Seebeck effect is an example of this. And with such methods, researchers in the USA have also managed to generate a power of 56 W with some setup.

But our topic is the performance class of supplying society and above all industry with a reliable power supply in the base load range (several 100 MW or 1 GW range), and such methods are simply not suitable for this.

The Conclusions. The procedure described is new and has not yet been put into practice.

Research perspectives:

- A correspondingly powerful upper heat exchanger, which functions as an evaporator and is pressure-resistant up to 20 bar, has to be developed.
- The Carnot cycle process with turbine or piston machine must be dimensioned.

But the investigation of the basic thermodynamics presented here gives reason to believe that the process in total works.

Research for comparable solutions, rights. I haven't found anything comparable. I did some internet research, which of course doesn't rule out the possibility that someone had this idea before me. If there is one, then he should contact me and prove his older rights. As long as this does not happen, I personally claim the rights to the idea for my own good, but also for the good of all mankind. The publication that happened here made it impossible to patent the idea and with it the well-known procedure that patents are acquired, but mankind is prevented from implementing the patents for profit reasons. I want to prevent this idea from ending up as a "drawer patent" in the drawer of a large company.

Request to refrigerant manufacturers, turbine manufacturers and geologists. I expressly request the first two to contact me for the purpose of a possible technical implementation of such systems. It is important to find suitable refrigerants with boiling points in the range of 20 – 35 °C that generate the highest possible vapor pressure during evaporation. And it is important to find turbines driven by steam pressure or gas pressure that work reasonably well even at low pressures.

I call on the geologists to think about possible locations where temperatures are as high as possible at depths of, say, 3000 m that are still technically easy to reach.

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