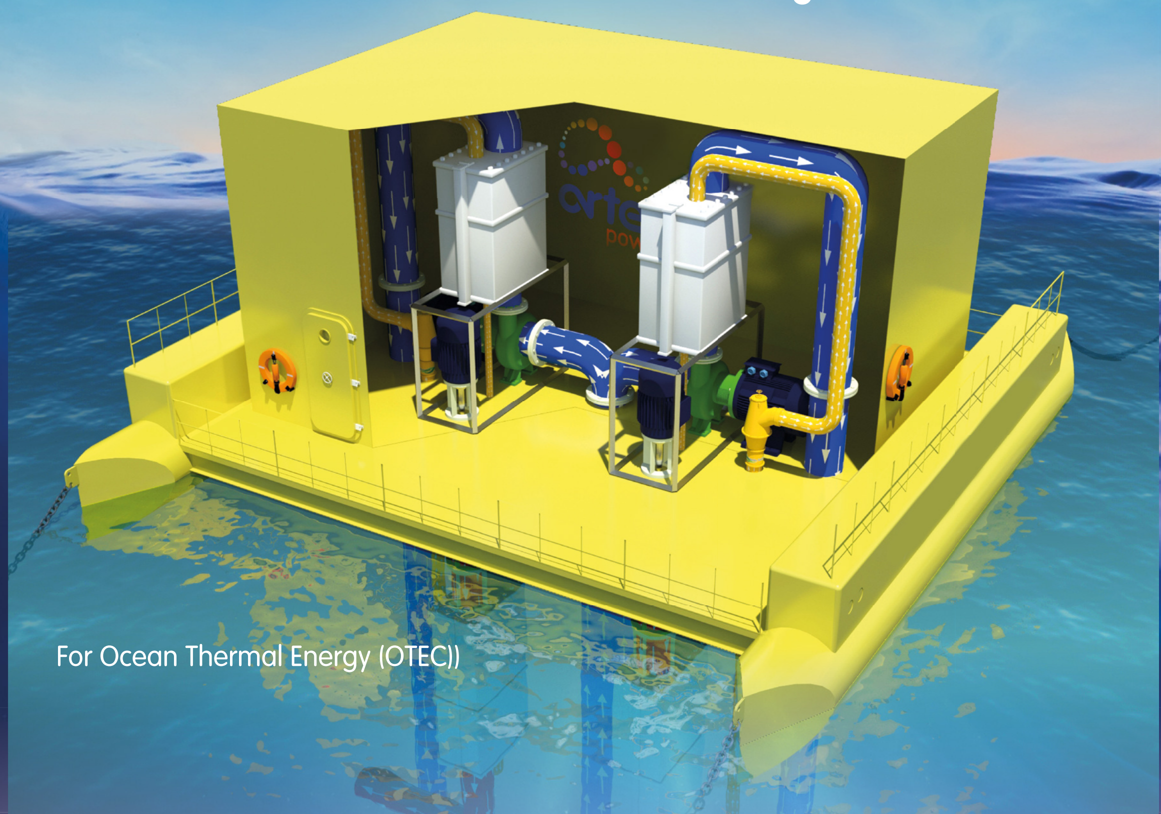
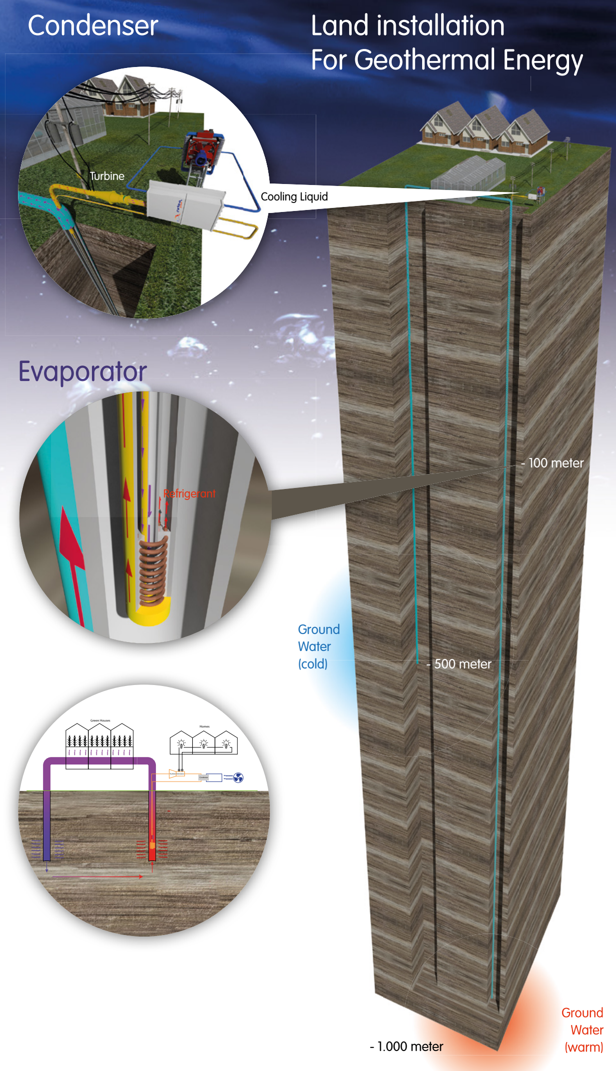
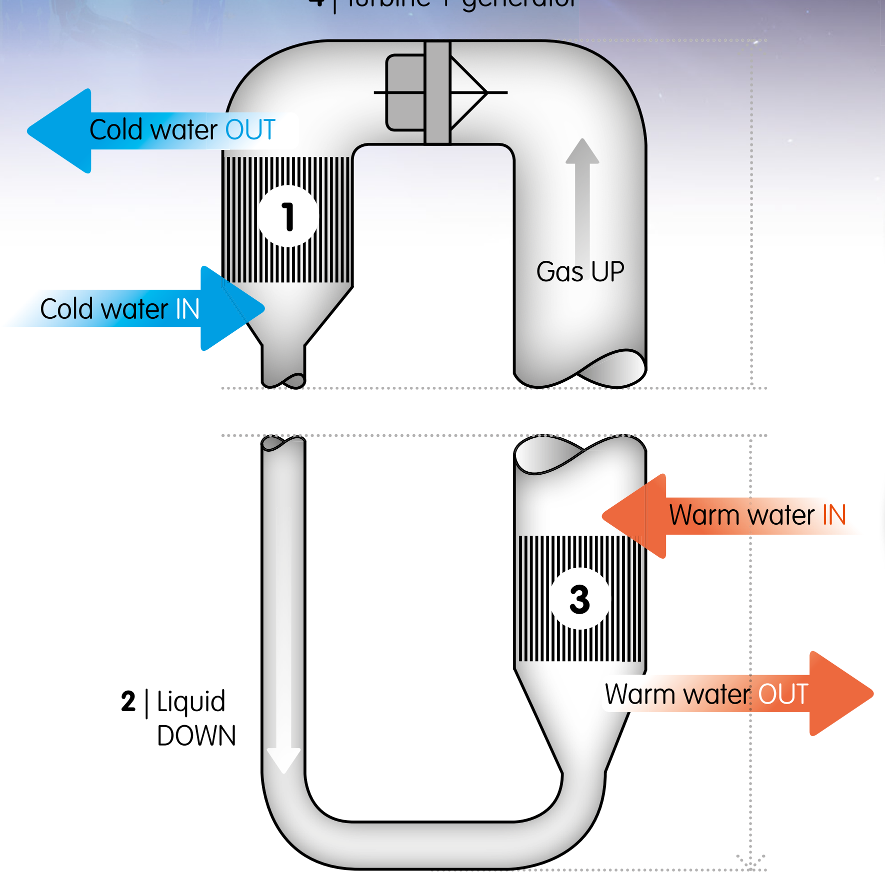
# ORC simplification




## Gravity pump plus thermosyphon for small temperature differences




## The natural way of pressurizing liquid is using the weight of the liquid column itself in stead of using a liquid pump




**Height** | 1~100
not to scale

| **Stages Archisol**
1 | Gas condensation
2 | Increasing liquid pressure
3 | Evaporation Superheater
4 | Gas expansion

A simplified ORC cycle is proposed for small temperature differences. The most important simplification is the replacement of the pump section by a hydraulic column. The weight difference between the downward moving liquid column and the upward moving gas column provides the driving pressure for the cycle. Because the effect of this weight difference bears resemblance to the principle of Archimedes, it is called the Archisol Concept

Especially for Ocean Thermal Energy Conversion applications, it is expected to be an advantage that less mechanical components are necessary for the cycle. The University of Wageningen has carried out some first order calculations to check the thermodynamic feasibility.
The calculation shows that it is possible to produce electrical power with the Archisol concept for both scenarios; ocean (Twater hot/cold = 27/6 °C) (i) and residual/geothermal heat (Twater hot/cold = 70/20 °C)

Typical for the ocean scenario is:

- The refrigerant cycle itself has a limited height, about 15 m, and operates with low pressure.
- A large part of the produced power output is consumed by the pumps of the evaporator and the condenser, which makes the outcome of the calculations very dependent on the energy consumption of the pumps. Most critical in the performance is the internal pressure drop of the water in the heat exchangers itself. The calculations are based on 0.3 bar pressure drop, but fact is that water supply lines are open systems, which can and will be polluted by dirt and biofouling, which can increase the water flow resistance strongly"

This leads to an efficiency of just over 2 % for the ORC cycle and 0,7 % for the complete process, taking secondary pump use for the water streams into account. The authors expect that the simplicity of the design could be attractive for further OTEC research and projects.

For the geothermal scenario the refrigerant cycle has a height between 50 and 100 meters and operates at medium pressure. The authors expect that this could be interesting where large streams of warm and cold water are easily available.

Further research is planned to demonstrate the viability of the proposed simplified ORC cycle.

A 1 kW pilot plant is envisaged to be built in the last quarter of 2015.

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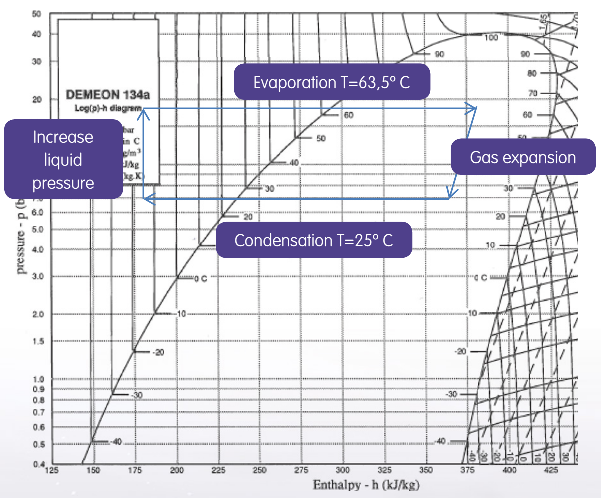
Main results of efficiency calculations ocean/refrigerant R134a scenario.

| Refrigerant | R134a | |
|---|---|---|
| | | |
| Power production turbine | 647 | kW |
| P elect LT water pump | 318 | kW |
| P elect HT water pump | 112 | kW |
| **Net power production** | **217** | **kW** |
| | | |
| **Condenser water transport pipe** | | |
| length | 600 | m |
| d-pipe | 1 | m |
| flow speed | 3 | m/s |
| Mass flow | 2419 | kg/s |
| Twater condenser in | 6.6 | °C |
| Twater condenser out | 9.6 | °C |
| | | |
| **Evaporator water transport pipe** | | |
| length | 11.63 | m |
| d-pipe | 1 | m |
| flow speed | 3.07 | m/s |
| Mass flow | 2475 | kg/s |
| Twater evaporator in | 27.0 | °C |
| Twater evaporator out | 24.0 | °C |
| | | |
| Δp condenser water pump | 0.92 | bar |
| Δp evaporator water pump | 0.31 | bar |
| Condenser capacity Qc | 28516 | kW |
| Evaporator capacity Qo | 29163 | kW |
| Maximum possible Carnot efficiency | 6.8 | % |
| **Calculated efficiency** | **0.7** | **%** |
| | | |
| **Height liquid column** | **12** | **m** |
| **Max system pressure** | **5.8** | **bar(a)** |
| **Total refrigerant contents** | **739** | **kg** |

Main results of efficiency calculations. Scenario: residual heat/ refrigerant R134a

| Refrigerant | R134a | |
|---|---|---|
| | | |
| Power production turbine | 2292 | kW |
| P elect LT water pump | 212 | kW |
| P elect HT water pump | 131 | kW |
| **Net power production** | **1949** | **kW** |
| | | |
| **Condenser water transport pipe** | | |
| length | 345 | m |
| d-pipe | 1 | m |
| flow speed | 3 | m/s |
| Mass flow | 2356 | kg/s |
| Twater condenser in | 20.00 | °C |
| Twater condenser out | 23.00 | °C |
| | | |
| **Evaporator water transport pipe** | | |
| length | 75 | m |
| d-pipe | 1 | m |
| flow speed | 3.07 | m/s |
| Mass flow | 2411 | kg/s |
| Twater evaporator in | 70.00 | °C |
| Twater evaporator out | 67.00 | °C |
| | | |
| Δp condenser water pump | 0.61 | bar |
| Δp evaporator water pump | 0.37 | bar |
| Condenser capacity Qc | 29547 | kW |
| Evaporator capacity Qo | 31839 | kW |
| Maximum possible Carnot efficiency | 14.6 | % |
| **Calculated efficiency** | **6.1** | **%** |
| | | |
| **Height liquid column** | **98** | **m** |
| **Max system pressure** | **18.2** | **bar(a)** |
| **Total refrigerant contents** | **6102** | **kg** |




Process cycle of gas expansion geothermal heat scenario indicated in h - log p diagram

## The optimal improvement of reliability of a component is by removing it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