Executive Overview of the REHOS Technology_Redone April 2018

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Abstract:

The REHOS cycle consist of two distinctly different sub-cycles, combined regeneratively, namely an Absorption Heat Transformer (AHT-VC Hybrid) type heat pump, pumping low-grade heat from the environment up to higher temperature, and a simple Organic Rankine Cycle (ORC) utilizing the pumped, higher temperature heat to power a turbine. The AHT is hybridized by the addition of a vapor compressor, forming a Heat Transformer type Heat Pump with an electrical component coefficient of performance (COP_e) very much higher than the conventional vapor compression (VC) heat pumps, (the AHT-VC Hybrid type heat pump use **both electrical and heat energy** for the heat pumping process, while the conventional **VC type use only electricity**). The ORC use the pumped higher temperature heat to power the turbine, and the turbine low pressure exhaust vapor (heat rejection) is recovered in the heat pump reactor bottom, where it is absorbed regeneratively, instead of rejecting the latent heat to an external cooling system. This regeneration provide (or rather, recirculation) a large portion of the heat required by the ORC, and only the energy shortfall (after complete heat balance of the cycle) is required to be added by external sources.

The **heat to power conversion efficiency** can therefore be calculated by the **ORC Output Power (with pumping and heat pump compressor power subtracted), divided by this energy shortfall,** and may thus be unbelievably high. This is also described in detail in other publications (listed as references to this document) most of which are published as downloadable pdf files from my website referenced [10].

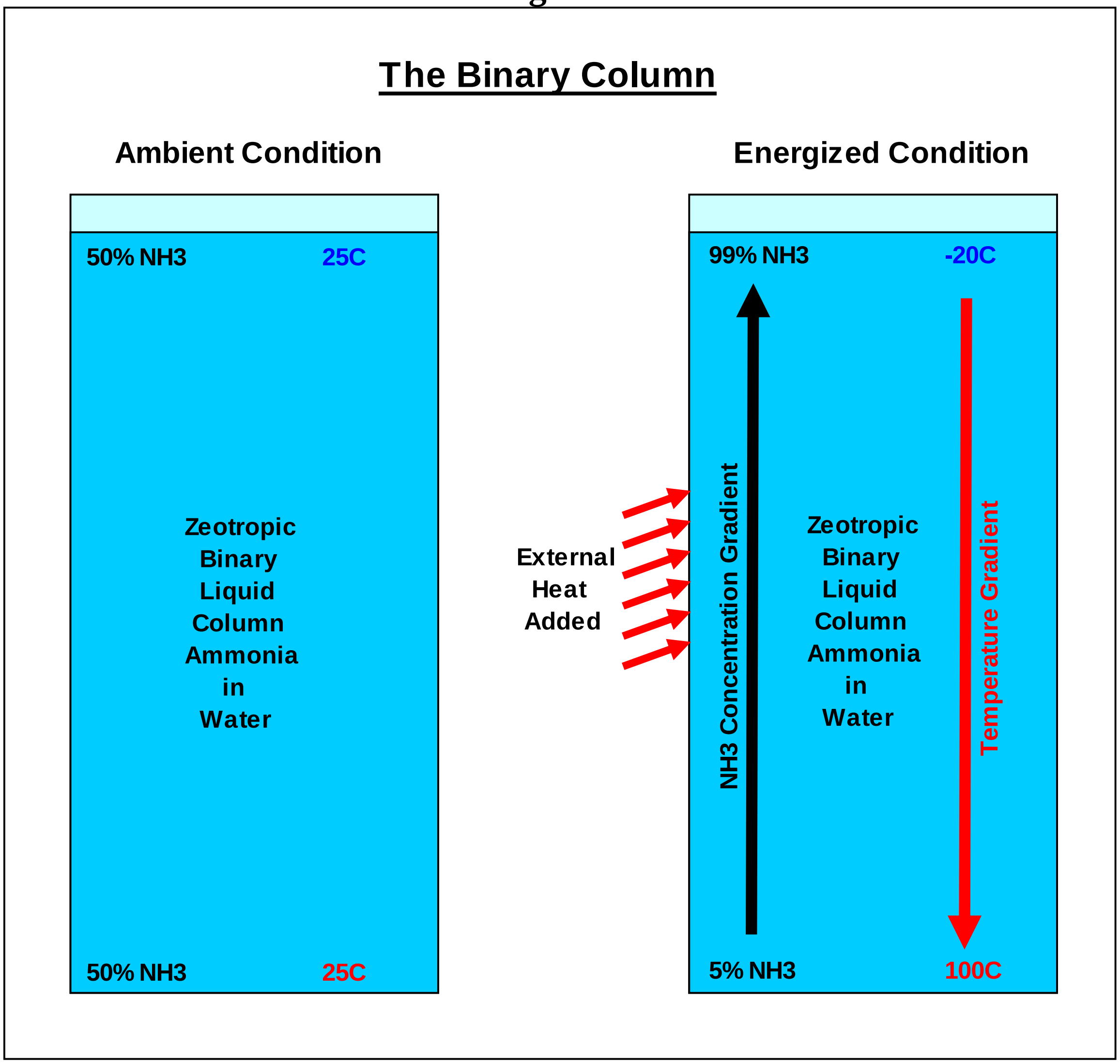
Introduction:

REHOS Technology, as well as costing methodologies, was already comprehensively described in several documents (see references at the end of this paper), but it is required to give an uncluttered executive summary to easily understand the revolutionary REHOS concepts.

Summary of REHOS concepts:

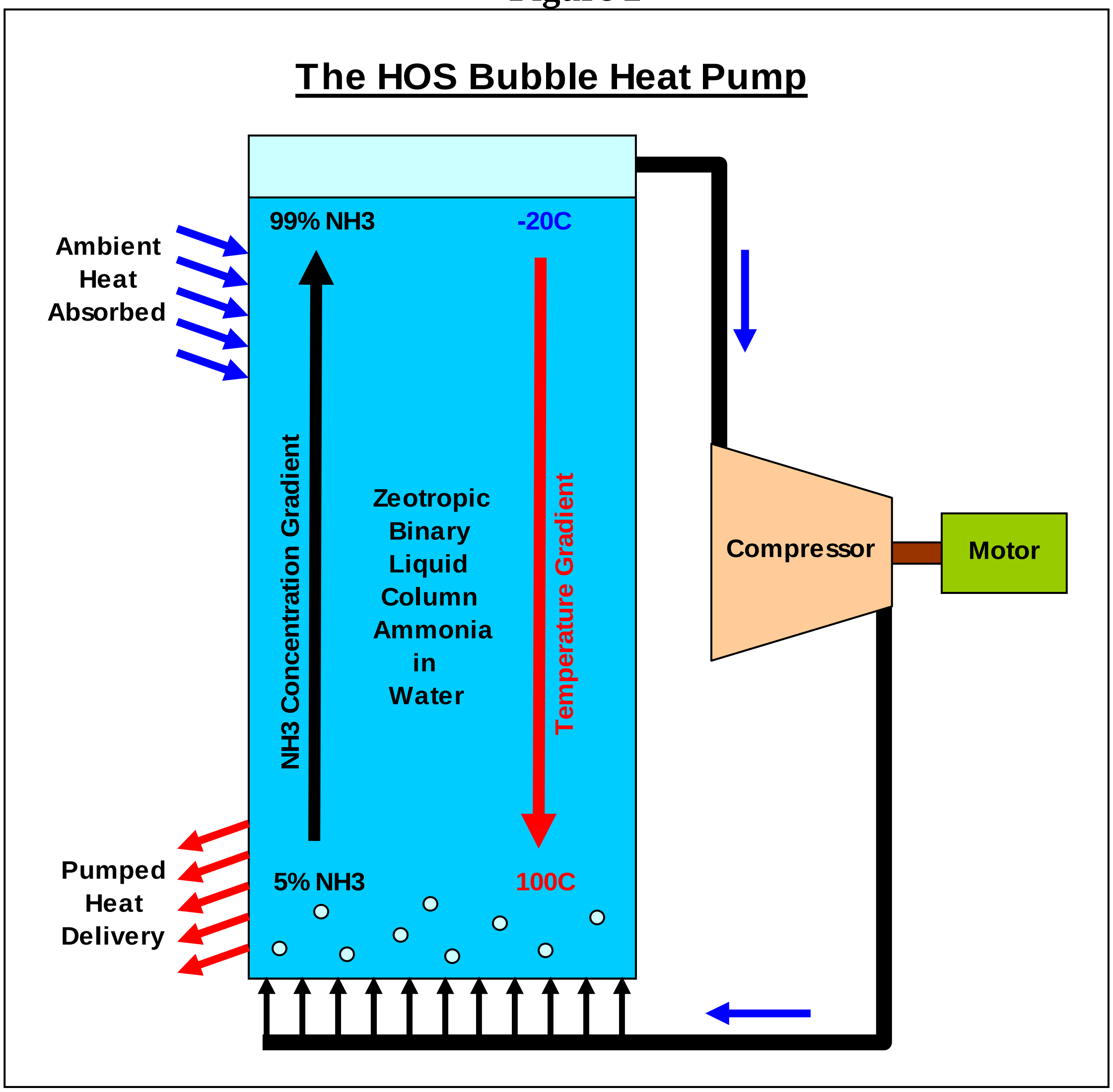
The heat of solution (HOS) concepts all stem from the physical characteristics of a zeotropic binary mixture in the vertical column reactor. This is sketched in Figure 1 below and the sketch accentuate the binary mixture reaction with heat added. On the left is the column at ambient conditions, with the 50% ammonia in aqua mixture filling the complete length of the column.

Figure 1



As soon as external heat is supplied to the column, the mixture react by creating an ammonia concentration gradient with the higher NH3 concentration moving to the top of the reactor while the higher density, hotter, but leaner NH3 mixture migrating to the bottom of the reactor. Simultaneously the mixture migrating to the top of the reactor cause a small amount of heat to be also carried upwards by the ascending vapor bubbles, while the reactor bottom is more severely heated by vapor bubbles being re-absorbed, creating a temperature gradient with the hottest area at the reactor bottom. Heat energy is required from external sources to establish this concentration and temperature gradient, but once established, the external heat source may be removed and the gradients would only very slowly dissipate, as heat is lost by radiation out from the hot bottom only. See also more detailed descriptions in my paper [1] presented at an international conference, as well as others [2] and [3] referenced at the end of this document. Convection mixing is prohibited as hot, lower NH3 concentration mixtures have a higher density than the

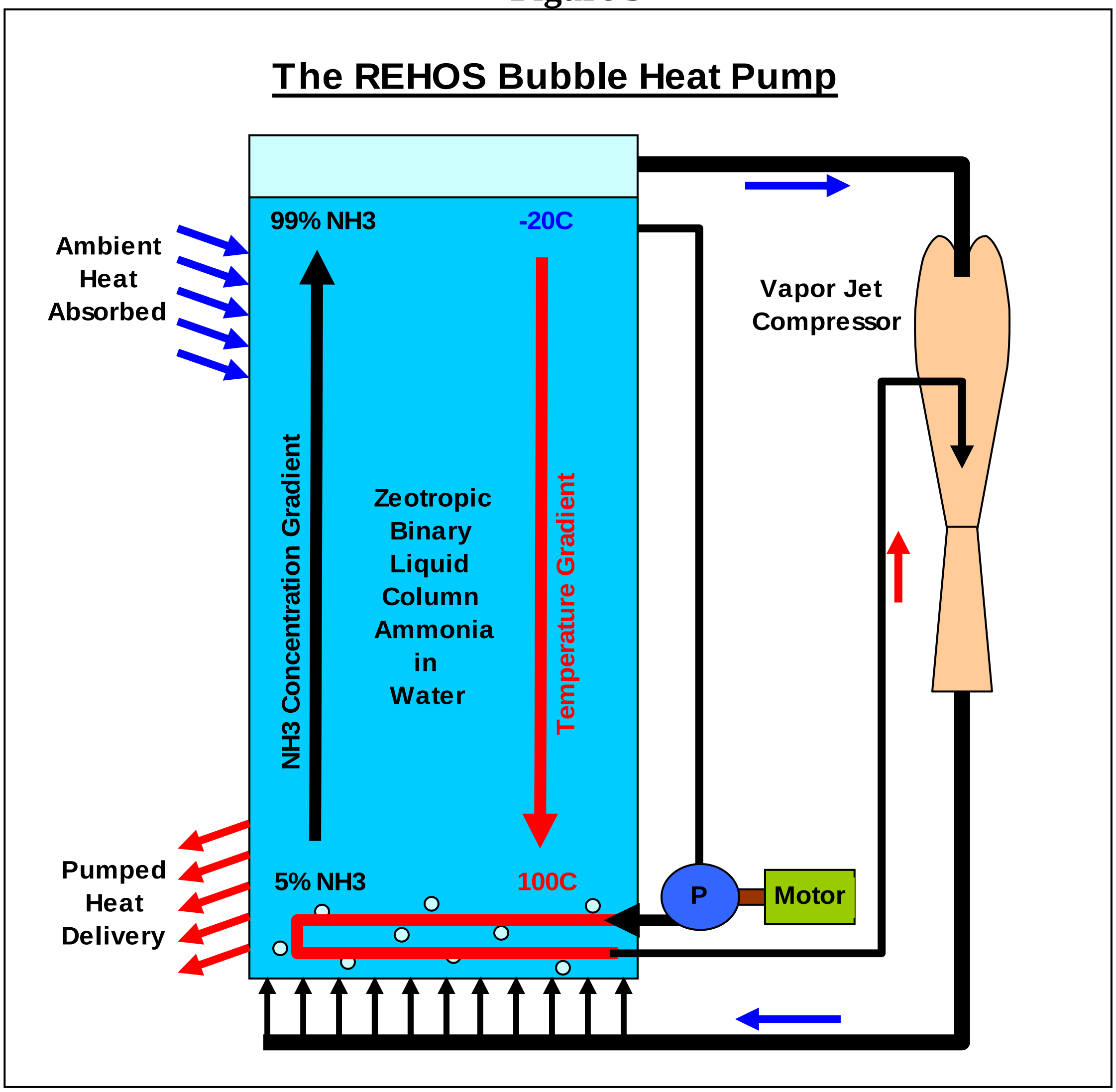
Figure 2



cooler, high concentration mixture. Note that due to the saturated nature of the binary column, external heat may enter the column anywhere along its length (therefore also at any temperature greater than the column temperature at the heat entry point), with the same effect.

Figure 2, above, sketch the heat of solution (HOS) bubble heat pump, detailed in my paper [8] where the performance is compared to other heat pumps. The electrical coefficient of performance (COP_e) of this type of heat pump is very high, as the compressor pressure ratio (and therefore temperature increase with pressure), is very small. The compressor only need to provide enough pressure to overcome the liquid column hydraulic pressure created by the gravity force on the liquid column. With the column mixture operating at the temperatures as shown, the compressed vapor

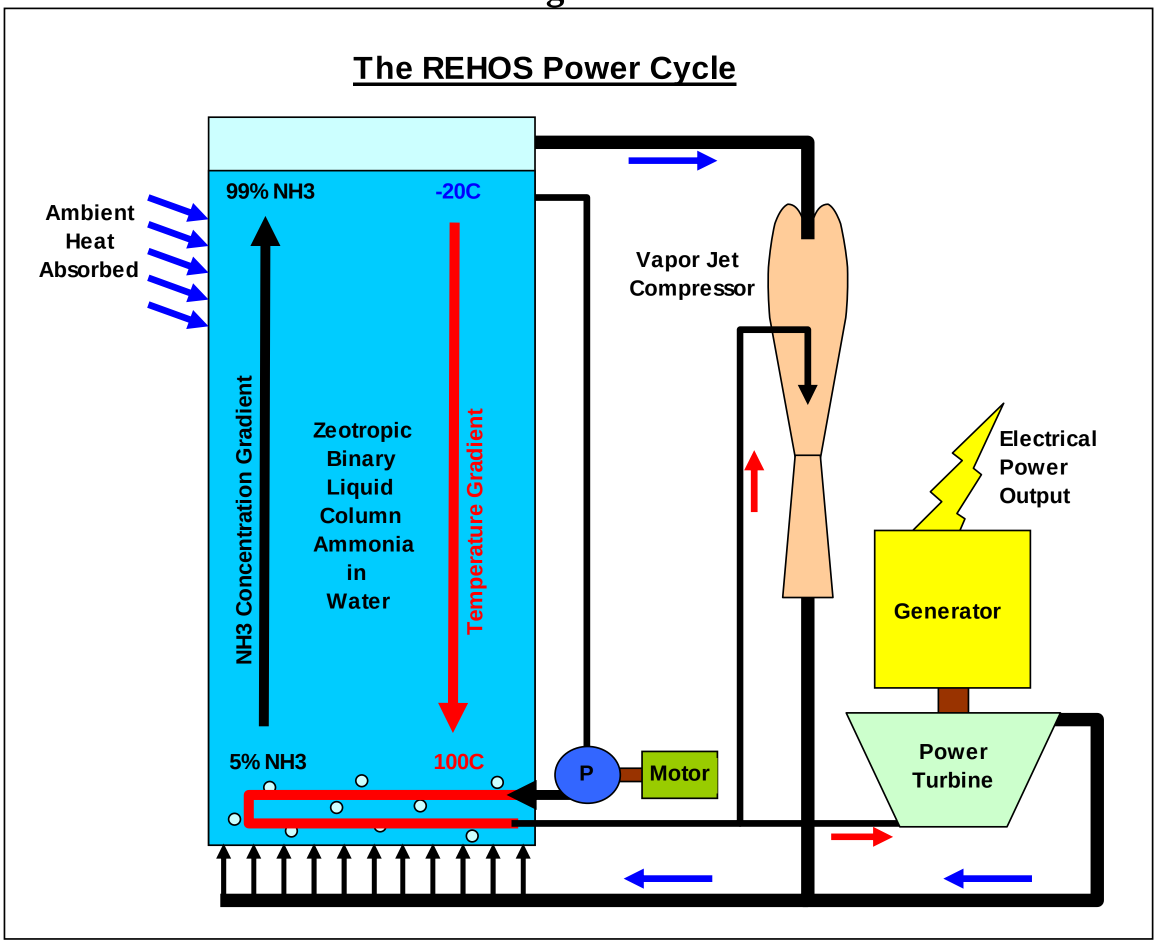
Figure 3



temperature only increase isentropically about 2 - 4°C, making the heat pump COP_e easily calculate to about 50-100. Remember that in heat transformer type heat pumps like this, the thermodynamic real COP_real is calculated as: $COP_{real} = \frac{Heat_{pumped}}{(Heat_{used} + W_{compression})}$,

but COP_e ignore the heat also used for the heat pumping process, and only deal with the electrical component of energy used for the heat upgrading process. See further clarification in my paper [7] emphasizing this principle. Cold compressed vapor bubbling into the heat transformer reactor is absorbed by the binary mixture, delivering heat to the reactor bottom and raising the reactor bottom temperature by 40 - 80°C (typical single stage AHT performance). The exceptionally high COP_e value (of 50 - 100), therefore does not only supply a heat pump operating with the small temperature delta of 2 - 4°C, but through the transformer action in the bubble reactor, generate a temperature delta of some 40 - 80°C, which is a factor of at least 20 x the performance of a conventional vapor compression heat pump which would have given a COP ~ 2.9 - 5, for the same 40 - 80°C temperatures. In the conventional vapor compression (VC) type heat pump the only

Figure 4



energy used for powering the heat pumping process is derived from electrical power in driving the compressor, in contrast to the AHT type heat pump using electricity as well as heat to drive this process. This give the **HOS heat pump a performance of ~ 20 times the conventional VC type heat pump (comparing electrical power used)**.

In the further enhanced regenerative heat of solution (REHOS) bubble type heat pump, we simply replace the motor driven isentropic compressor with a vapor ejector type compressor, using regenerative heat of absorption of the vapor bubbles at the bottom of the reactor to evaporate the pumped, high pressure liquid in a heat exchanger positioned in the hot bottom of the bubble reactor. This injector type of compressor therefore use a very small amount of electrical energy to only drive the liquid pressure pump (and obviously a much larger component of heat). The REHOS type heat pump COP_e is therefore a factor of several times the HOS heat pump performance, putting it's performance into the range of COP_e = 300 - 600, or a factor of **~ 100 to 300 times the conventional vapor compression type heat pump!**

The REHOS power cycle sketched in Figure 4, differ from the REHOS heat pump in figure 3 only in the removal of a heat output (heat sink), and use of the pumped heat high temperature energy to evaporate a lot more liquid, to power a vapor expansion turbine for the purpose of generating electrical power. The low pressure exhaust of the turbine adds to the compressor output vapor, to be regeneratively re-used in the reactor bottom for the evaporation process. The **REHOS power cycle therefore have an extremely high heat to electricity conversion efficiency of 80 - 90%**, making it the ideal low temperature waste heat to power energy recovery machines. My detailed explanations for this high efficiency in referenced paper [8] would help understand this better.

Environmental heat can be extracted from the environment, as the cold end of the reactor operate at some 20°C below zero, resulting from the vapor compressor removing (flashing) vapor from the reactor top. A simple liquid-liquid heat exchanger can therefore extract ambient heat from water sources like rivers, streams, dams, lakes and the sea to generate power from, at the revolutionary high (> 80%) REHOS cycle efficiency!

Extracting heat from a liquid like water, has a very high power density in the required heat exchangers, due to the large medium density and sensible heat content of the ambient temperature water. The heat exchanger to do this is therefore small and cheap, while extraction of heat from the air has a much lower density and heat capacity. The heat exchangers are therefore much more bulky and expensive. In cases where very small amount of power would be required, (like powering a lightweight electrical bicycle for example) it would be practical, however.

The useful side effect of extracting heat from ambient air would obviously deliver chilled air (for air conditioning and refrigeration use) as well as a de-humidifying effect, condensing water vapor from humid ambient air. In the proof-of-concept model proposal of the document [9] the "water extracted from air" in de-humidifying operation is elaborated on.

More uses of the REHOS technology is detailed in the paper [5] to demonstrate the enormous market for this refrigeration / power generation technology.

Publications:

1. Paper presented at PowerGen Africa Conference July 2017 and published in the conference proceedings titled "Introducing a novel thermodynamic cycle (patent pending), for the economic power generation from recovered heat pumped from the huge global thermal energy reservoir called earth" by Johan Enslin, Heat Recovery Micro System CC. This paper is also accessible from my website http://www.heatrecovery.co.za/.cm4all/iproc.php/PowerGen-Africa 2017 Proceedings Speaker0_Session19149_1.pdf

2. A Paper titled "The Simplified REHOS Cycle.pdf" was written by Johan Enslin in August 2017 and published on my website http://www.heatrecovery.co.za/.cm4all/iproc.php/The Simplified REHOS Cycle.pdf

3. A Paper titled "Clarifying Process Parameters for the REHOS Cycle Concept_rev3.pdf" was written by Johan Enslin in October 2017 and published on my website http://www.heatrecovery.co.za/.cm4all/iproc.php/Clarifying Process Parameters for the REHOS Cycle Concept_rev3.pdf

4. The Paper titled "The Binary NH3-H2O Bubble Reactor_rev1.pdf" was written by Johan Enslin in December 2017, but as yet unpublished. Should you need this document, contact myself at: mailto:johan.enslin@heatrecovery.co.za

5. The Paper titled "The Competitive Advantages of REHOS Technology_rev1.pdf" was compiled by Johan Enslin in early January 2018, and published on my website http://www.heatrecovery.co.za/.cm4all/iproc.php/Competitive Advantages of REHOS Technology_rev1.pdf

6. Another paper, "Executive Overview of the REHOS Technology_rev1.pdf" was compiled by Johan Enslin in February 2018 and published on my website http://www.heatrecovery.co.za/.cm4all/iproc.php/Executive Overview of the REHOS Technology_rev1.pdf

7. The follow-up document "Clarification of COP calculations for Absorption Heat Transformer (AHT) Type Heat Pumps.pdf" was written by Johan Enslin (to enhance the Executive Overview paper) in March 2018 and published on my website http://www.heatrecovery.co.za/.cm4all/iproc.php/Clarification of COP calculations for Absorption Heat Transformer (AHT) Type Heat Pumps.pdf

8. The document titled "Comparison of various Modern Heatpump Technologies for unlocking Commercial Value from Ambient Heat_rev4.pdf" was written by Johan Enslin in April 2018 and published on my website http://www.heatrecovery.co.za/.cm4all/iproc.php/Comparison of various Modern Heatpump Technologies for unlocking Commercial Value from Ambient Heat_rev4.pdf

9. The Paper titled "The Proof-of-Concept Model of the REHOS Ejector Heat Pump_Part 1.pdf" was written by Johan Enslin in April 2018, but as yet unpublished. This document was produced for the purpose of detailing the design, construction and theoretical operational performance of the Heatpump and would be followed up with a Part 2 document, representing the experimental process performance of the tested Model. Should you need to read this document, contact myself at: mailto:johan.enslin@heatrecovery.co.za

10. Website for Heat Recovery Micro Systems where the above publications are available from: www.heatrecovery.co.za