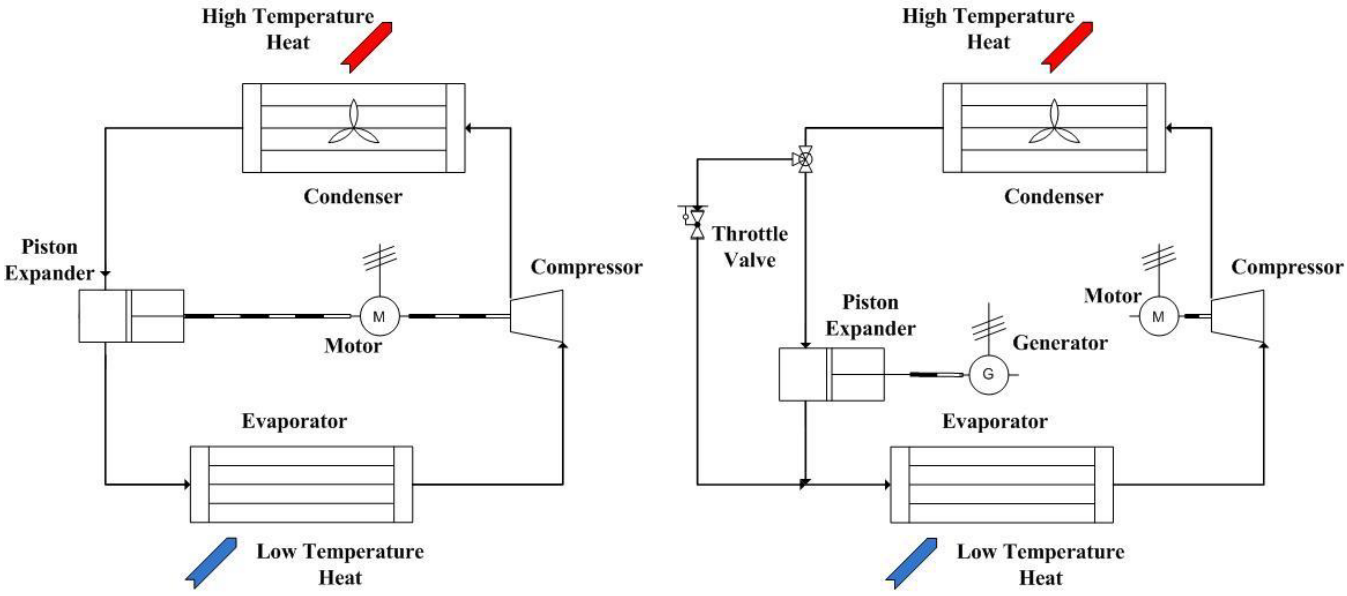

Figure 1. Vapour-compression cycle using an expander (in cooling mode): a) new heat pump unit (mechanical coupling), b) retrofitting design (electricity generation)

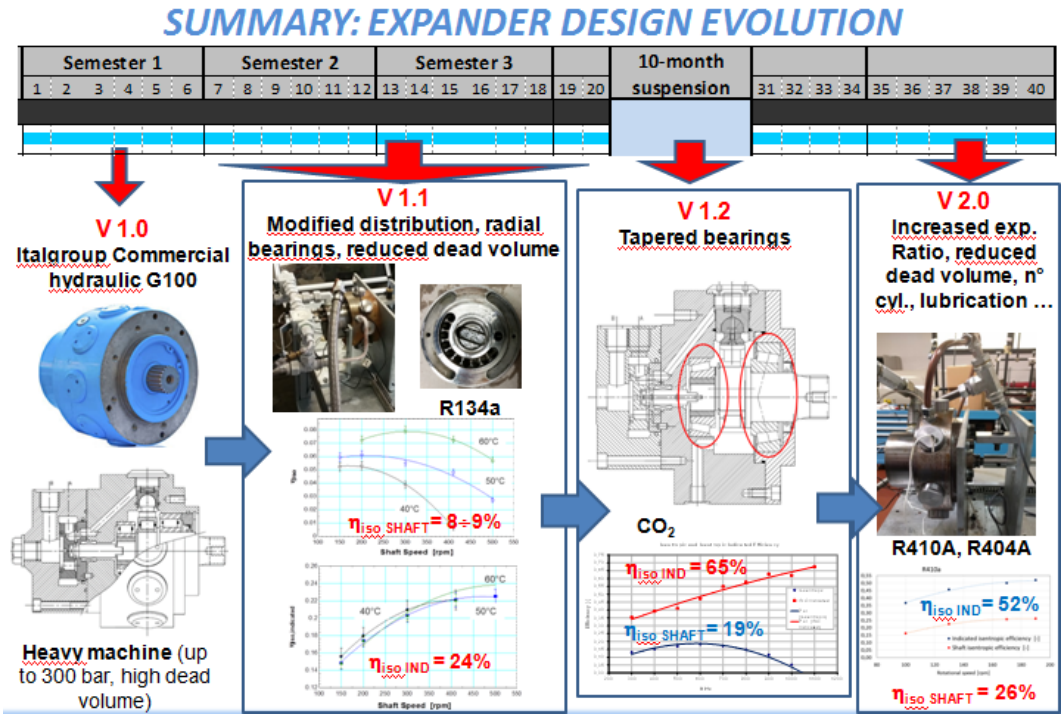

Figure 2. Evolution of the developed dedicated expander design

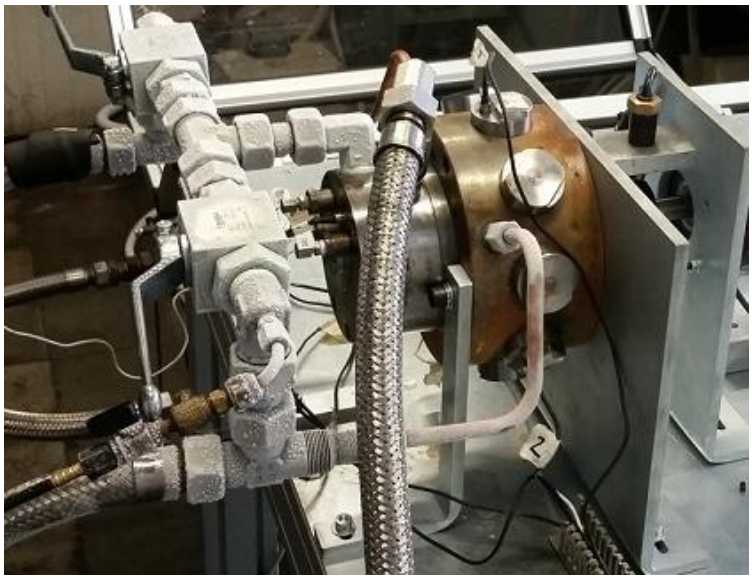

Figure 3. Manufactured expander version 1.1, mounted on test rig

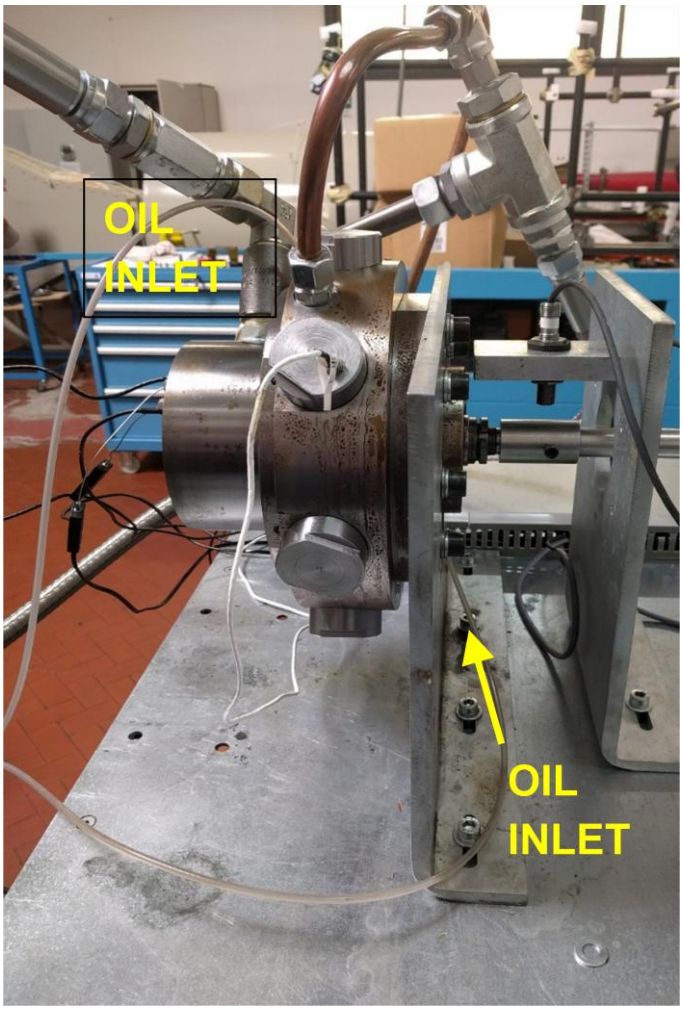

Figure 4. Manufactured expander version 2.0, mounted on test rig

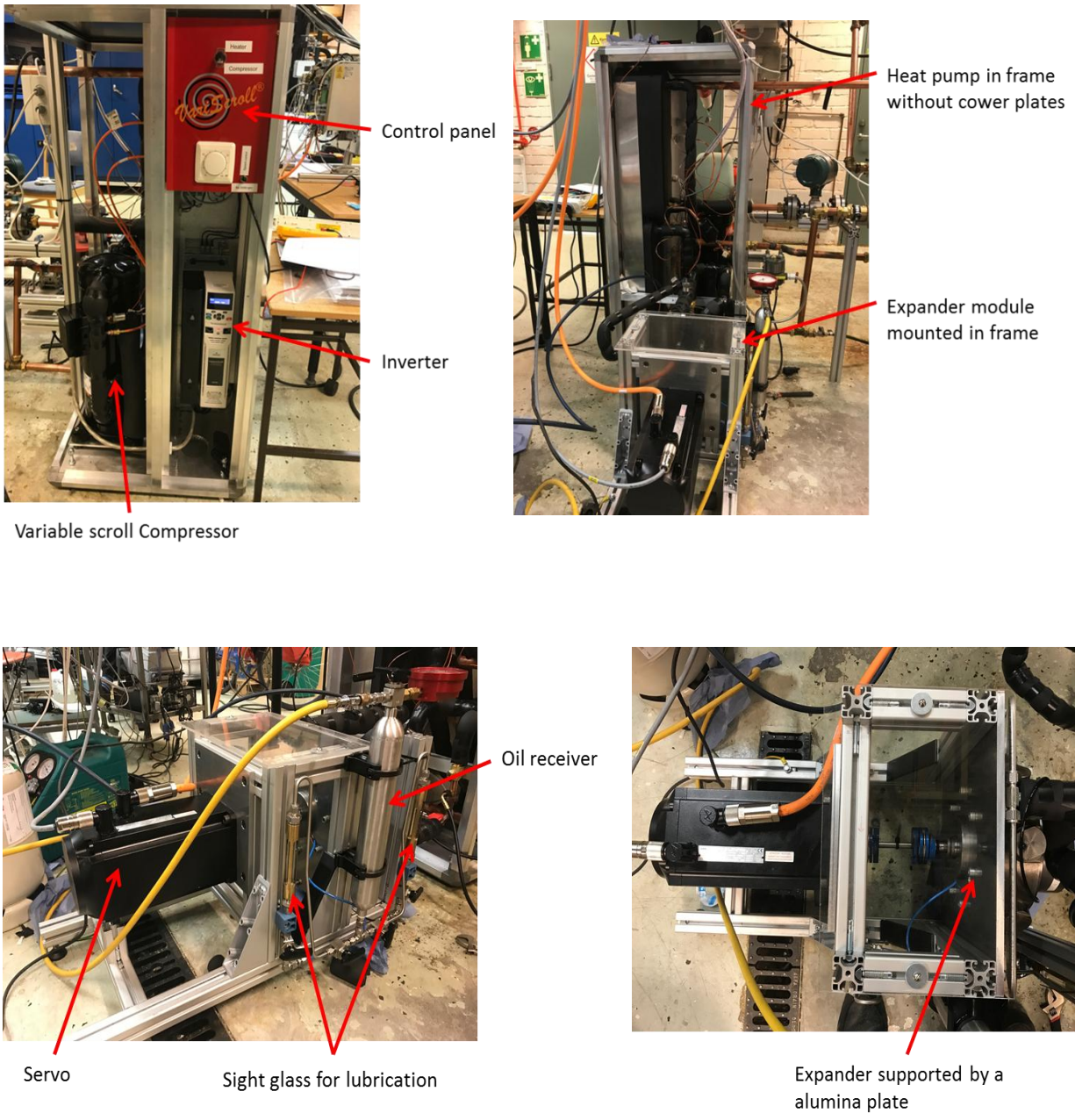

Figure 5. The new heat pump test bench

Figure 6. The retrofitted heat pump test bench

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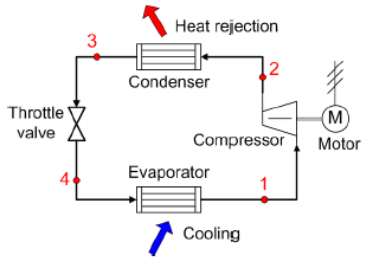
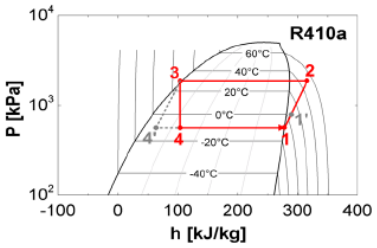
Research for the benefit of SMEs

Energy recovery in new and retrofitted heat pumps using a dedicated expander concept

The Vapour-Compression Cycle (VCC)

Heat pumps are used to transfer heat from a low temperature environment to a hotter one with the use of work. Their operation is based on the Vapour-Compression Cycle (VCC):





Simple VCC at cooling mode: a) schematic diagram, b) pressure/enthalpy chart

The main processes of a simple VCC are:

1→2: Compression of the refrigerant vapour (Mechanical Work)
2→3: Condensation of the refrigerant vapour (Heat Rejection)
3→4: Throttling/expansion valve (Isenthalpic Process)
4→1: Evaporation of the two-phase refrigerant (Effective Cooling)

The Coefficient Of Performance (COP):

Cooling Mode: $COP_{cool} = \frac{Q_{cool}}{W_c} = \frac{h_1 - h_4}{h_2 - h_1}$

Heating Mode: $COP_{heat} = \frac{Q_{heat}}{W_c} = \frac{h_2 - h_3}{h_2 - h_1}$

The COP of a Heat Pump can be increased:

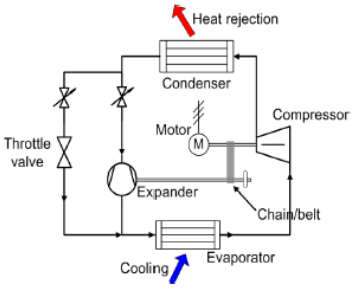
a) At Cooling Mode by increasing the removed heat (Q_{cool}) OR/AND by reducing the compression work (W_c)

b) At Heating Mode by reducing the compression work (W_c)

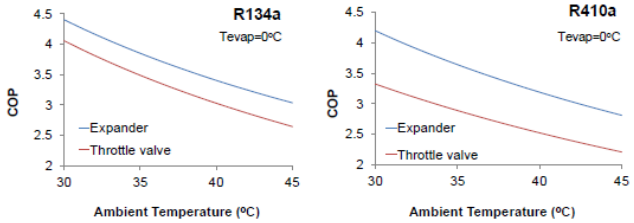
Substitution of the throttling valve with an Expansion Machine

The main concept is to replace the throttle/expansion valve used in common VCC units with an expansion machine, and thus to recover energy from the high-pressure condensed refrigerant (state 3 in the P-h diagram). The mechanical energy can be directly provided to the compressor, reducing its electricity consumption. Then, the overall COP of the system can be increased in both cooling and heating mode.

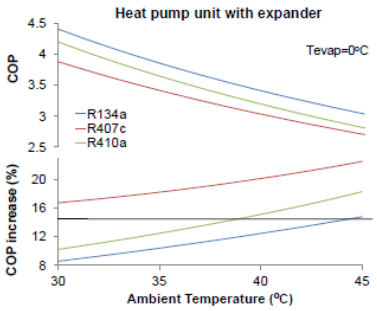
Moreover, at cooling mode, the heat removed (Q_{cool}),is increased, since the expansion of the liquid refrigerant is not isenthalpic (state 4 is moved towards the saturated liquid curve at state 4' in the P-h diagram).



Work recovery potential in small-sized heat pumps (10-20 kW net cooling capacity)



Impact of the integration of an expander on the COP in cooling mode



COP and COP increase vs. ambient temperature in cooling mode

Objectives

- ✓ Design, manufacture and testing of a reciprocating liquid expander
- ✓ Its integration in a new re-designed high-end heat pump unit and its testing
- ✓ The retrofitting of a conventional heat pump unit and its testing

National Technical University of Athens (GR) – Coordinator

Universita degli Studi di Firenze (IT)

Thermogas SA (GR)

Italgroup SRL (IT)

Kungliga Tekniska Hoegskolan (SE)

Officine Mario Dorin SPA (IT)

Eureftec AB (SE)

FP7-SME-2013

GRANT AGREEMENT NO: 605923

Figure 7. EXP-HEAT poster

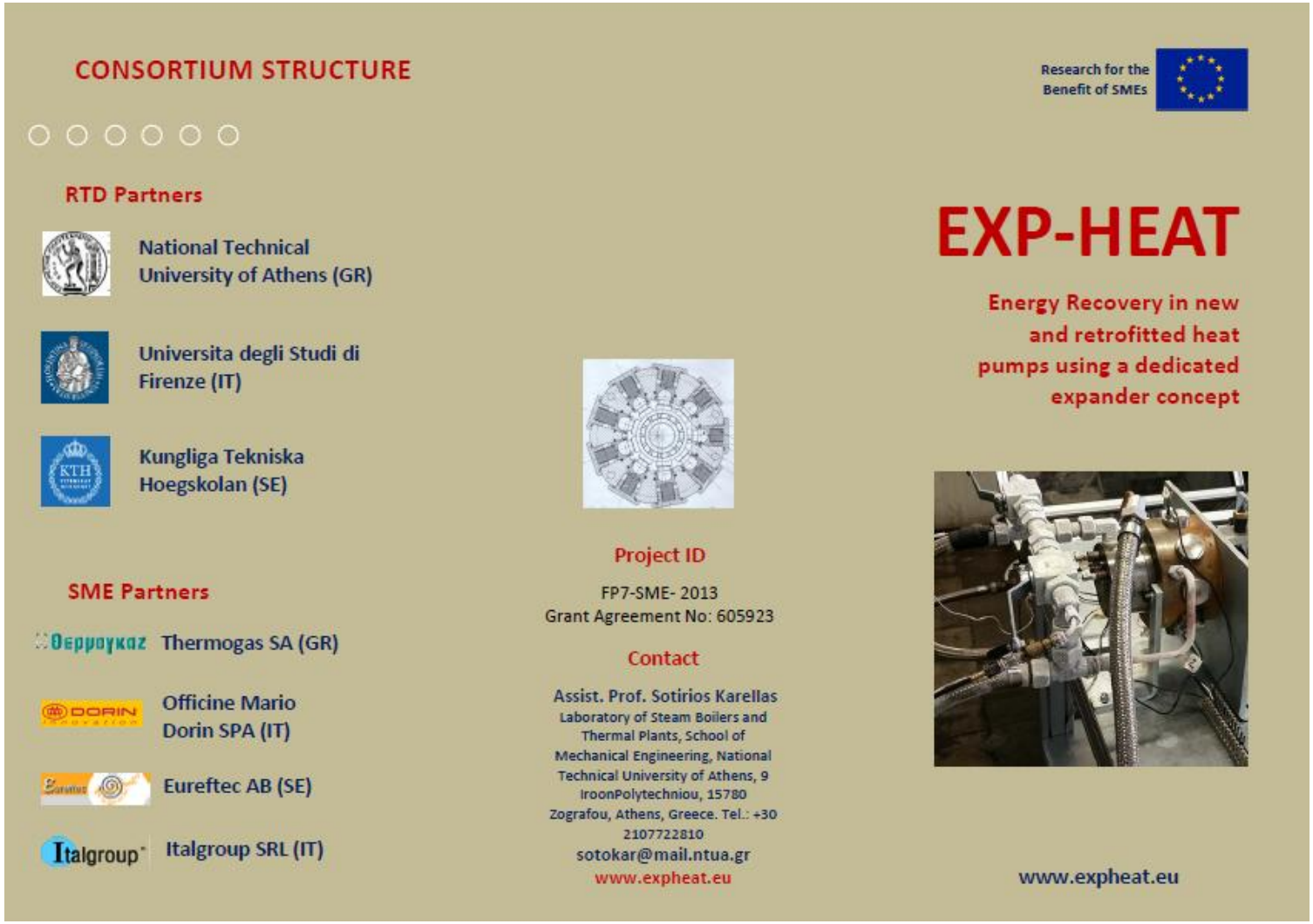
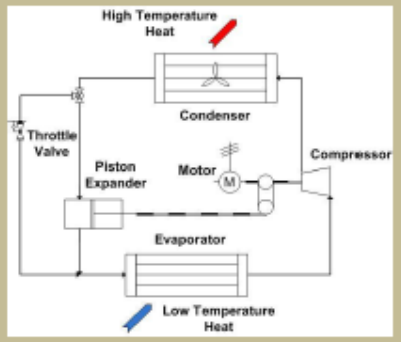


Figure 8a. EXP-HEAT leaflet

PROJECT CONCEPT

The main concept of the EXP-HEAT project is to replace the throttle or expansion valve used in common vapour-compression units with an expansion machine. Its purpose is to recover energy from the high-pressure liquid (condensed) refrigerant and provide it to the compressor, reducing its electricity consumption.



DEDICATED LIQUID EXPANDER

A dedicated liquid expander will be developed within the EXP-HEAT project. Actually a hydraulic piston motor will be re-designed and modified to serve this purpose (Cover Photo). Its optimization will be achieved using CFD tools and extensive experimental testing.

S&T OBJECTIVES

The strategic technical objective of the project is to improve the performance of heat pump units by integrating the new piston expander .This concept will finally lead to performance increase, while keeping the cost of the expander low, in order for the specific operational cost and pay-back-period of this combined unit to be significantly reduced.

RE-DESIGNED COMMERCIAL HEAT PUMP UNIT

Integration of the expander in a re-designed commercial heat pump unit will require a slightly different design, which will be investigated during the project. Also, the control unit will have to be modified in order to optimize the combined system efficiency.

RETROFITTED HEAT PUMP UNIT

The developed expander will be retrofitted to an installed heat pump unit, in order to boost its performance. The relevant know-how that will be gained during its testing will result in a retrofit kit capable to be used in a wide range of heat pumps and compressors

EXPECTED RESULTS

The overall objective of the project is to open new markets for the participating SMEs, and further develop new products and services, in order to magnify their business cycle.

THE HEAT PUMP MARKET

An improved re-designed heat pump unit of higher efficiency offered at slightly higher cost will be introduced by EURE, while it is anticipated to have a very low pay-back-period, securing its cost effectiveness. On the other hand, the retrofit kit can be installed in a variety of heat pumps and boost their performance. This can be achieved with limited effort and cost, putting THERMO in a leading position.

OTHER POTENTIAL MARKETS

The same expander (perhaps modified) can be also integrated in refrigeration or air-conditioning units, enhancing their performance. Moreover, the 1-2 kW expander has the potential to be used for micro-scale applications like ORCs, where this technology has the potential to become competitive with micro-turbines, which typically require very high rotational speeds.

Figure 8b. EXP-HEAT leaflet