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NATURAL GAS AND HEAT PUMPS : RECENT DEVELOPMENTS FOR INDIVIDUAL HOUSING

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ABSTRACT

In a moving energy and environmental context, it is important to develop more efficient natural using products, to answer to the market and regulations requirements. GDF SUEZ is leading developments in the field of heat pumps for individual dwellings. Two technologies are being investigated. The first is hybrid heat pump, that is combining the best from an electric heat pump and a gas boiler, with a smart control system able to choose the most efficient one depending on the parameters of functioning. The second is an absorption heat pump, that is using the outside air and natural gas as energy sources to produce heating and domestic hot water.

Those products have big opportunities in a context where the efficiency of energy using products becomes more and more important. For environmental and energetic aspects, gas efficient heating and domestic hot water systems like hybrid heat pumps and absorption heat pumps are relevant because enable a interesting efficiency progress, by using a part of renewable energy. Furthermore, these systems have a promising potential market because of the economic competitiveness for new and retrofitted individual dwellings.

Several steps of development have been followed in partnerships with manufacturers to develop products. First, the specifications of each product were defined in collaboration with manufacturers, in order to:

Develop heating and domestic systems that are combining all the targets according to the different European directives concerning environment and energy saving.

Be compatible with a production process and the market demand, particularly concerning the investments and running costs.

In a second step, two prototypes have been tested in experimental houses: seasonal efficiency can be measured on a real building where the presence of inhabitants is simulated. These tests have started at the beginning of the winter 2010-2011 and have already shown some important considerations.

For hybrid heat pump, this test was particularly important to check that the unit was compatible with the installation inside the house, respecting the noise specification and reliable. Now the manufacturer is implementing the control strategy to optimize the efficiency depending on primary energy. The next field tests will demonstrate the seasonal efficiency.

For the absorption heat pump, a conceptual prototype has provided indication of a promising efficiency with a seasonal gas utilization efficiency of 1.31 (net calorific value) on the test house near Paris. The result is consistent with the simulation done thank to a preliminary mathematical model established by extrapolation of laboratory tests results. On the basis of these initial indications, the manufacturer might decide to start the development activities, which include for example optimization of the control strategy and creation of a complete system with all the hydraulic components to be adapted to the market. Field tests on conceptual prototypes are planned during the winter 2011-2012, to continue this investigation phase. The goal is bringing the benefits of gas absorption heat pump technology to the residential market at the earliest possible date.

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1 DEVELOPMENT OF NEW GAS USING PRODUCTS TO COMPLY TO THE EFFICIENCY IMPROVMENTS REQUIREMENTS

The environmental and energy context is moving on. Europe has a strong engagement with the 3x20 objective: 20% CO2 reduction, 20% Energy efficiency, 20% renewable energy before 2020. As responsible for 37% of the global energy consumption in Europe, the domestic energy consumption of buildings will be a crucial sector to achieve this commitment.

In Europe, the Directive for Energy Performance of Buildings (1) is setting a major guideline, like thermal regulation in France (RT2012). While efforts should first focus on the envelope, a global approach should include all positions to improve the maximum energy performance, what of course include the heating and domestic hot water generator.

In parallel, the Energy Using Product Directive (2) is working on labeling for heating systems (lot 1) and domestic hot water systems (lot 2). This labeling has the objective to show to the consumer which product is the most efficient, and the directive has the aim to forbid the selling of too poor efficient systems.

Other European directives will more and more push to use the best technology to produce heat and will promote all the systems using a part of renewable energy.

In a meantime, the final customer is moving on decreasing the environmental footprint, but without decreasing his comfort and in a “cost sensitive” way.

Today the gas boilers are very competitive and efficient solution for heating and domestic hot water (DHW), but to comply with all this evolution, it is important to develop more efficient technologies. The association of heat pumps and natural gas have in this context an interesting market opportunity. Indeed, some systems like boilers or electric heat pumps (EHP), boilers combined with solar, exist on the market as heating and domestic hot water (systems, but they still carry some limitations:

The condensing boiler has reached its maximum in terms of performance, with an efficiency of about 107%.

Low temperature EHPs are not or poorly suited to the production of heat at temperatures above 50 °C, despite it is needed for DHW or into renovation. To ensure the highest temperatures, they use an extra electric resistance. This has the effect of increasing the peak electricity demand, which is the largest source of CO2 emissions.

The high temperature EHPs are emerging on the retrofitting market. Because of the high compression (through the use of multi-stage compressors), the energy gain for the more efficient is estimated at about 10% of primary energy compared to a condensing boiler with an investment cost much higher.

The association of a condensing boiler with solar energy is a good way to associate renewable energy with natural gas, but those systems have limited use of renewable particularly in heating mode because depending on the solar energy and the investment cost is still a limit to be very competitive.

If other solutions are currently under development, such as micro CHP based on Stirling engine in the short term, or fuel cells in longer term, hybrid heat pumps and natural gas heat pumps will complete the road map of heating and domestic hot water products.

Hybrid heat pumps are combining a small electric heat pump with a boiler, with a smart control strategy that is able to choose the most efficient system by considering the primary energy. It is combining the benefits of both systems: at average outside temperature and average water temperature, the electric heat pump provides good efficiency by using a part of renewable energy, when the boiler provide better efficiency at low outside temperature and hot water production. The technology development using two well known technologies, the market launch is already starting in 2011 to answer to a short term product need.

Natural gas driven heat pumps are heat pumps where thermally driven reactions, adsorption or absorption followed by a desorption step activated by a simple burner replace the compressor. If one producer has already started to commercialize one unit, it seems that a real product offer will be ready in a couple of years.

This product associates the use of renewable energy with natural gas, which gives it performance-oriented and environmental benefits compared to high temperature Electric Heat Pumps. Indeed, beyond the significant energy efficiency on heating but also DHW, this heat pump helps to reduce peak electricity consumption to reduce CO2 emissions, a major issue in the EHP rational development.

In this context, CRIGEN (one of the R&D center of GDF SUEZ) collaborates with manufacturers to develop these two products. CRIGEN participates at several levels like : the definition of the initial set of characteristics of the product, economic studies to make comparison with others systems, tests (in laboratories and in the field), and also the integration into the appropriate regulations or incentives.

This paper will provide an overview of heat pumps combined with natural gas dedicated to individual housing and focus on two co-developments : one monobloc hybrid heat pump dedicated to new dwellings, developed with ELM LEBLANC (French brand of BOSCH) and then an absorption heat pump developed with ROBUR dedicated to housing retrofitting.

2 STATE OF THE ART: HEAT PUMPS DEDICATED TO INDIVIDUAL HOUSING

2.1 Electric heat pumps

The European electric heat pump market is expanding: it has been multiplied by 2 since 2005 to reach 490 962 units in 2010 (3). The principle of functioning of this technology is to use a cold source, air, water or brine, to heat a hot source, the building, via water emission system, radiators or heating floor for example, or the inside air directly.

Most of the EHPs are not able to produce hot water because of technical limits to reach a water production temperature not exceeding 50°C-55°C. But this trend is changing and now high temperature heat pumps are coming on the market: DAIKIN, DIMPLEX, STIEBEL ELTRON are examples of providers. This technology has however a high investment cost compared to classic electric heat pumps.

Concerning the efficiencies, the standard EN 14511 defines nominal conditions depending on the type of electric heat pump. For example, most of the market-available air/water heat pumps have a nominal coefficient of performance (COP), at 7°C outside temperature and 35°C outlet temperature (7°C/35°C) between 3 and 4. In Europe, the regulations or incentives consider the primary energy consumption. As a consequence, the COP has to be divided by 2.5, which is the current European conversion factor (4). So considering the primary energy, the efficiency can be considered for most of the market between 1.2 and 1.6. In France, the conversion factor to consider primary energy for electricity is 2.58. This paper will then consider this value because the opportunity of development where investigated for the French market by GDF SUEZ.

2.2 Hybrid heat pumps

A hybrid heat pump is defined in this paper as the association of a small electric pump with a boiler thanks to a smart control system able to choose the most efficient system on primary energy depending on the running conditions and the building needs. The simple association of a boiler and EHP without smart energy control strategy is here not considered.

There are two configurations of hybrid heat pump:

- Monobloc system, the boiler and the electric heat pump are integrated in the same bloc and installed inside the house.
- Bi-blocs system, the electric heat pump is installed outside the house and the boiler inside the house.

Currently two hybrid heat pumps are available on the French market:

- Saunier Duval, product commercialized since 2009.
- Ariston, product commercialized since June 2011.

The technical characteristics of each of these products are presented table 1 and 2.

System configuration	Bi-blocs	 Inside unit  Outside unit
Boiler	Capacity (kW)	6.9 - 29.5
	Efficiency (%) 80°C/60 °C Net Calorific Value (NCV)	98
Electric heat pump	Technology	Inverter
	Capacity 7°C /35°C (kW)	3.0
	COP 7°C /35°C	4.0
	Capacity 7°C/45°C (kW)	2.6
	COP 7°C/45°C	3.02
Control system	Energy prices	

Table 1 : ARISTON hybrid product “Talia Green hybrid”.

System configuration	Bi-blocs	 Inside unit  Outside unit
Boiler	Capacity (kW)	8.4 - 25.8
	Efficiency (%) 50°C/30 °C Net Calorific Value	107
Electric heat pump	Technology	Binary on/off
	Capacity 7°C /35°C (kW)	4.70
	COP 7°C /35°C	3.73
	Capacity 7°C/45°C (kW)	4.41
	COP 7°C/45°C	3.02

Control system	Primary energy

Table 2 : SAUNIER DUVAL hybrid product “Genia hybrid”.

Currently, the ELM LEBLANC monobloc hybrid product is beeing developed in collaboration with GDF SUEZ and will be detailed in part 3.

2.3 Sorption heat pumps

A sorption gas fired heat pump operates like an electric heat pump in this way: a cold renewable heat source is used to heat a hotter sink, the heating/DHW water, thanks to a working fluid. It follows a classical thermodynamic cycle with the steps of condensation, expansion, evaporation. What is different is the compression step, which is replaced by a thermally driven reaction, between the working fluid, and a sorbent. This step is usually composed of several phases :

- Absorption or adsorption: the vapor and low pressure refrigerant will be adsorbed or absorbed by the sorbent, to form a liquid or solid mixture.
- For liquids, a solution pump is used to increase the pressure.
- And finally, a gas burner brings the energy to separate again the two components and evaporate the refrigerant, which is now at high pressure.

2.3.1 Gas Absorption Heat Pump

This figure shows a simplified operating cycle of an ammonia/water absorption heat pump. The refrigerant is ammonia, and the absorbent is water.

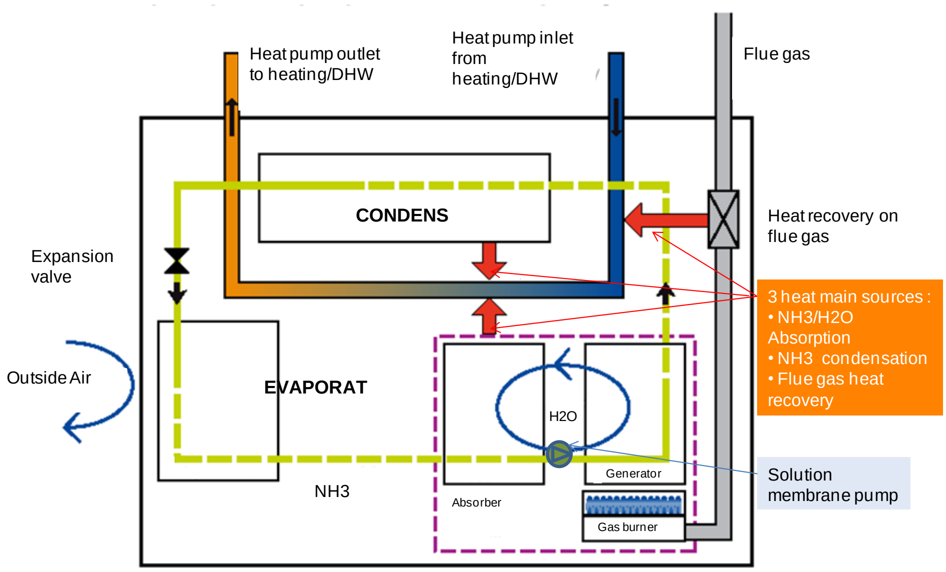


Figure 1: Simplified principle scheme of an ammonia/water GAHP

2.3.2 Gas adsorption Heat Pump

This figure shows a simplified operating cycle of an adsorption heat pump that uses water as working fluid and zeolite as adsorbant. This heat pump uses solar as cold source, and water for the emission system. This heat pump has only one bed, i.e. one reactor containing the refrigerant, water, and the zeolite. Because of that, the process will be discontinuous. The first phase is evaporation/adsorption. Thanks to the cold source, the refrigerant, water, evaporates and is adsorbed by the zeolite. The heating during this phase is produced by the exothermic adsorption reaction. As soon as the zeolite is full of water, the phase changes: the burner starts and brings the heat to desorb the water from the zeolite. This water will be condensate to provide the heat to the building.

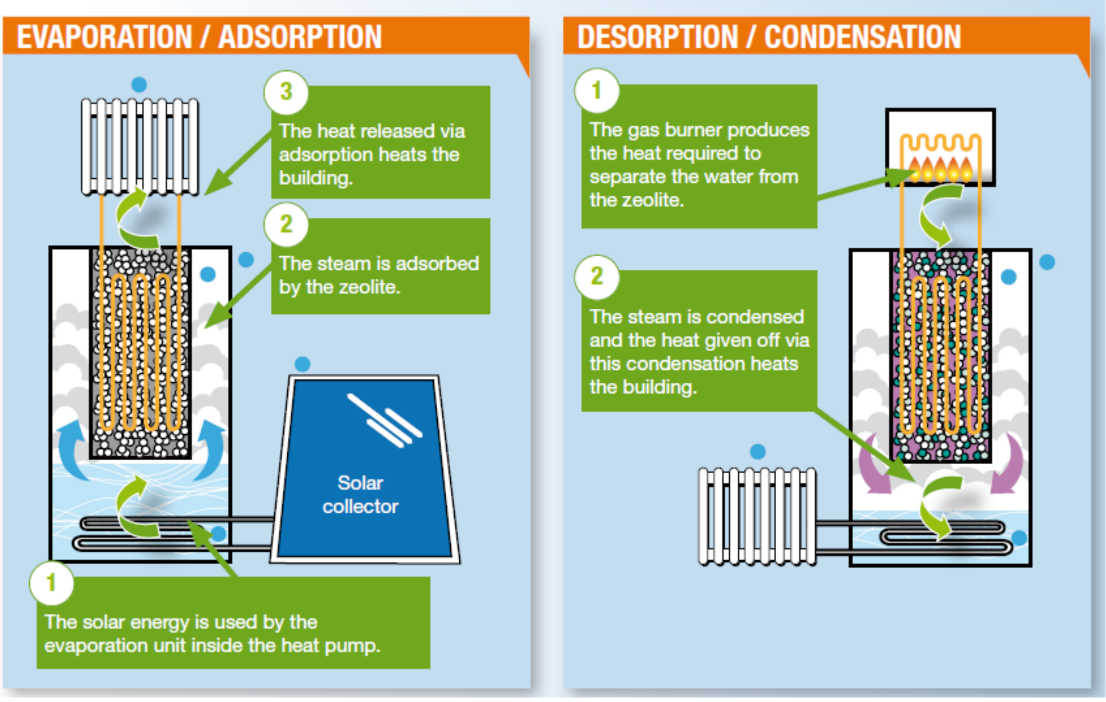


Figure 2: The operation cycle of an adsorption heat pump with one bed is separated in two phases: evaporation/adsorption and desorption/condensation.

It is also possible to have multi bed adsorption heat pumps, in order to have in a meantime the two phases and make the process more continuous.

2.3.3 Current sorption heat pumps developments

ROBUR is selling an absorption heat pump dedicated to collective dwelling or commercial building since 2006. In excess of 6,000 units are now installed in Europe, in air source version (air/water) or geothermal version (brine/water or water/water). For individual housing, ROBUR is considering a smaller version of this heat pump. This intention will be detailed in part 4.

Other gas fired heat pumps are currently being developed in Europe, dedicated to individual housing. VIESSMANN and VAILLANT develop zeolite adsorption heat pumps, operating with solar or geothermal cold source, and preferentially distributing the heat by heating floor. This two systems have the distinctive characteristic to have a small heat pump capacity around 5 kW that is completed by a boiler mode to provide 10 kW or 16 kW thermal output. The big advantage of this technology beyond the efficiency aspect, is the very silent operating cycle, since there are no moving part. This point also assures a light maintenance, similar to a boiler. In addition, the working fluid is water, what prevent from any sanitary and environmental consideration related to the refrigerant. VAILLANT is already selling the product in Germany and VIESSMANN targets a market launch in 2013. The target efficiencies are between 127% (5) and 136% (6) on net calorific value (according to the Germain guideline VDI 4650-2).

As other development, the British start up SORPTION ENERGY is working on an air/water adsorption heat pump. The working fluid is ammonia, and the adsorbent is carbon. As the bed is very compact, a four bed prototype has been created. This prototype should be tested in 2011. The theoretical efficiency is promising: 1.54 net calorific value at 5°C ambient temperature, 35°C water outlet temperature (7).

VIESSMANN is working on an absorption heat pump using a innovative working pair. The seasonal efficiency target is 145 % on net calorific value (8) (according to the German guideline VDI

4650-2). This development concerns first a geothermal version but an indirect air version is in theory feasible.

All these developments are summed up in the table 3. These projects have different market launch target, but 2013 should start the gas fired heat pump market with at least two different versions commercialized. A complete product range with different sources and adapted to existing or new dwellings should be available very soon after this year.

MANUFACTURERS	ROBUR	SORPTION ENERGY	VIESSMANN	VAILLANT	VIESSMANN
Type	Absorption	Adsorption	Adsorption (Zeolite)	Adsorption (Zeolite)	Absorption
Renewable source	Air	Air	Geothermal	Solar	Geothermal
Priority market, most adapted (other market are nevertheless possible)	Existing dwellings	Existing/New dwellings	New dwellings	New dwellings	New dwellings
Maturity	Investigation	Investigation Currently making a first prototype	Field test	Market launch first quarter 2010 in Germany	Investigation

Table 3 : Several gas fired heat pump developments.

3 MONOBLOC HYBRID HEAT PUMP DEVELOPMENT

3.1 A concept of product defined to be adapted to new individual housing

The objective of this new concept developed in collaboration with ELM LEBLANC is to get the advantages of condensing boilers and electric heat pumps while limiting their weaknesses. This comparison is presented figure 3.

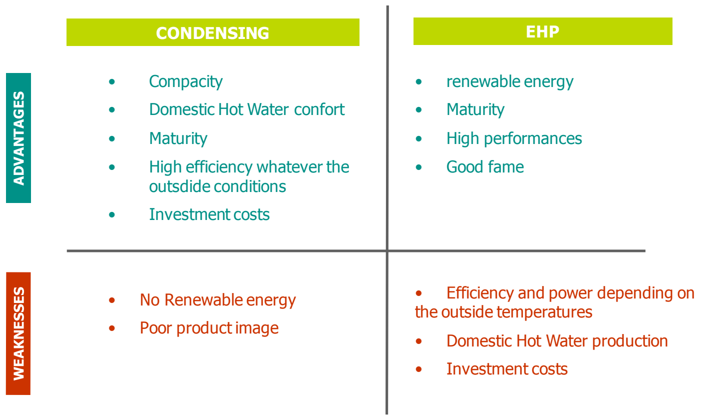


Figure 3: Comparison between condensing boiler and electric heat pump

The innovation of this product is to combine intelligently these two technologies in a compact product. The size is 10% more than a boiler. This kind of product will be the first on the French market.

The control system chooses the technology which consumes less primary energy. The target is to reduce the primary energy consumption about 15% less than a condensing boiler.

3 operating modes are possible depending on external conditions and heating demand.

- Heat pump only: The heat pump provides all the heating needs and the heat pump is more efficient than the boiler.
- Heat pump + boiler: The heat pump is more efficient than the boiler but it does not provide all the heating requirements.
- Boiler only: The boiler is more efficient than the heat pump.

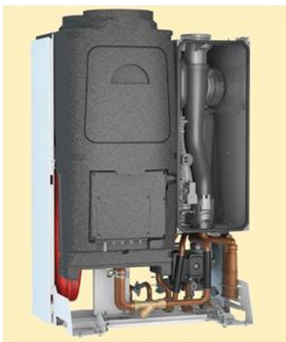
The key development points are various:

- The system has to be compact and makes acceptable noise to be installed inside the house.
- Best efficiency on primary energy. As the efficiency is depending on the outside temperature, the humidity, the heating and domestic hot water demand and the temperature level required, it makes a lot of parameters that has to be evaluated in details to create a control strategy that offers the best compromises.
- Using a part of renewable energy to comply the requirements of the next thermal regulation.
- Adapted for the new buildings. Indeed, it is a priority market where a system more efficient than a boiler is needed, because of the thermal regulation increasing requirements.

Simulation studies were conducted to determine the most adapted heat pump output capacity, taking into account the following parameters:

- Compactness of the product.
- No defrost system.
- No reversibility.
- Adaptability of the heat pump for small heating needs (the new home market).
- Easy to install (limited diameter of the inlet and outlet air holes for the heat pump).
- Customer comfort.
- Electric capacity subscription equivalent to a condensing boiler.

The results show that is relevant for the market to have a heat pump capacity not exceeding 3 kW, because allows a small compressor, that is cheaper, and assure a good seasonal efficiency.

System configuration	Monobloc	
boiler	Capacity (kW)	4 - 24
	Efficiency (%) 50/30 LHV	104
Electric heat pump	Technology	Binary on/off
	Capacity 7°C/35°C (kW)	2.2
	COP 7°C/35°C	3.5

Regulation system	Energy primary
Heating system	Heat pump + condensing boiler
Domestic Hot Water System	Condensing boiler

Table 4 : First characteristics of the hybrid heat pump.

The next step is to implement the product with the possibility to prepare domestic hot water.

3.2 Potential energy savings and economic aspects

GDF SUEZ has developed a software, called OCSYGEN®, which compares the hybrid heat pump cost (customer invoice) and energy (primary energy consumption) to other heating systems.

The figures 4 and 5 present the results for a new house of 110 m² in the North East area (This geographical area has the coldest weather, so it represents an unfavorable case for heat pumps). The emitter used is a heating floor. All the calculations are made with the actual French regulated prices (Cost of 1 kWh of gas (high calorific value) is about 5,24 cent€ and 12,84 cent€ for electricity).

We compare the hybrid heat pump with two products:

- A condensing boiler,
- An electric heat pump. In this case, the domestic hot water is produced with a thermodynamic tank.

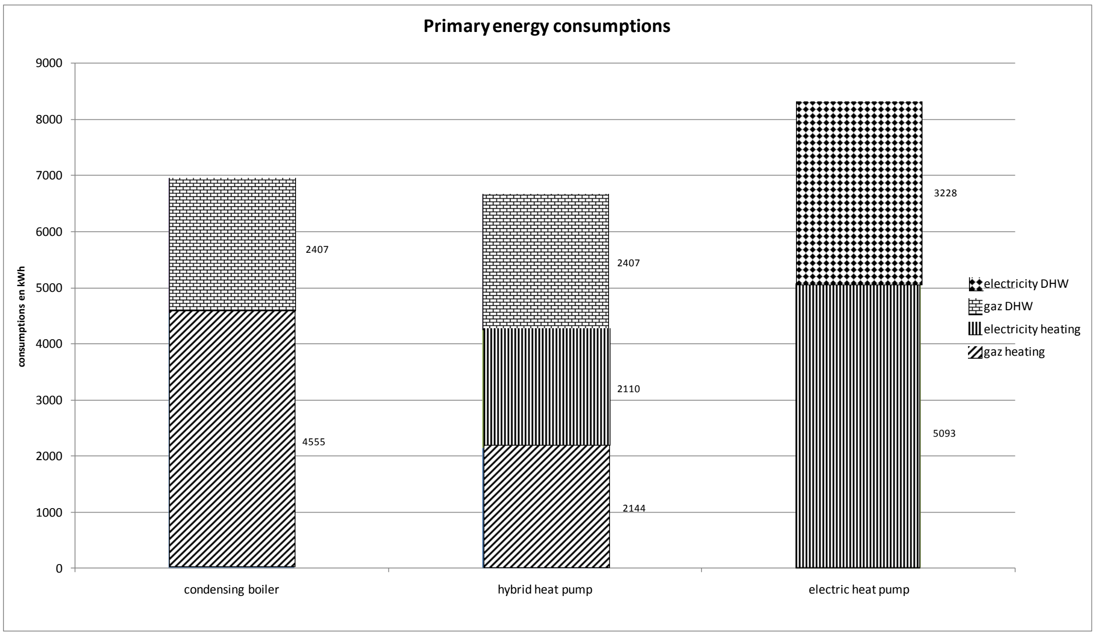


Figure 4: Even in a cold climate, in a new house, the hybrid heat pump provides interesting primary energy saving.

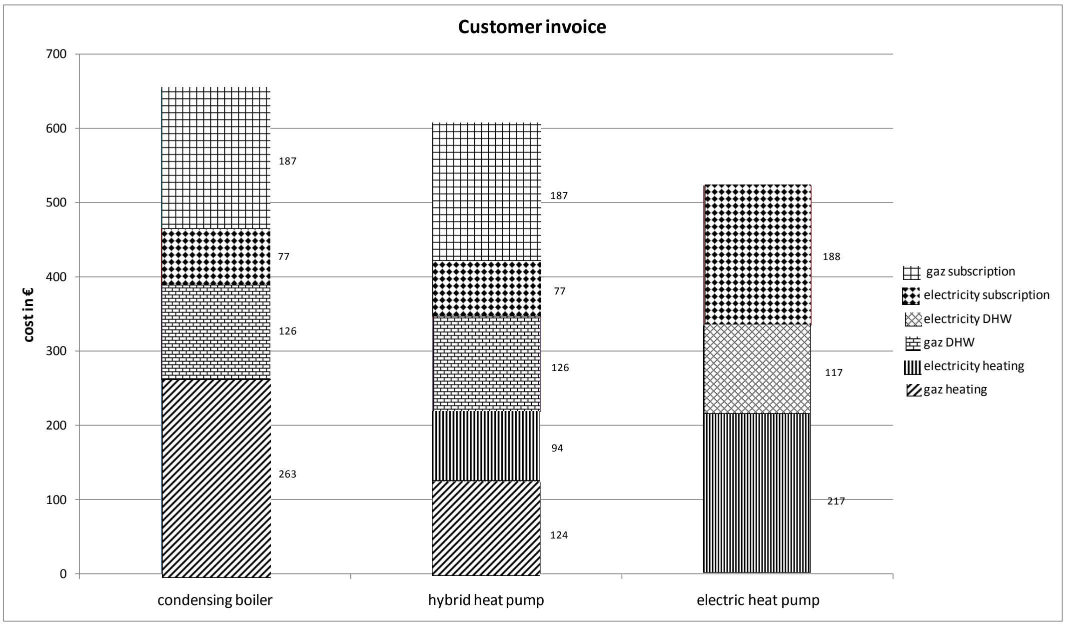


Figure 5: In a new house, the hybrid heat pump energy cost is between boiler and EHP.

The hybrid heat pump in case of new building provides 7% of primary energy saving compare to a boiler and 17% compared to and EHP. If it represent 4% of energy cost, this point can still be optimize by preparing domestic hot water with the heat pump from the hybrid system. In this simulation, the boiler only assumes this production. Furthermore, the investment target cost of the hybrid heat pump is less than an electric pump. This is manly feasible because of the small size of the compressor.

Figures 6 and 7 present the results for a retrofit house of 110m ² in the North East area. The emitters used are low temperature radiators.

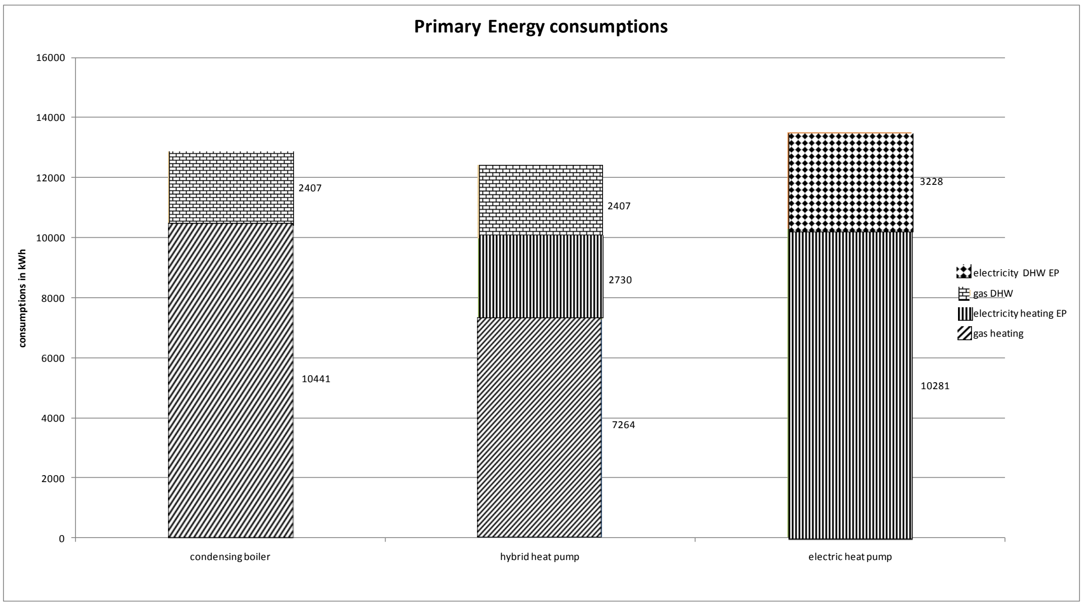


Figure 6: In a retrofit houses in a cold climate, the hybrid heat pump provides 2 % energy saving compared to a boiler and 7% compared to an electric heat pump.

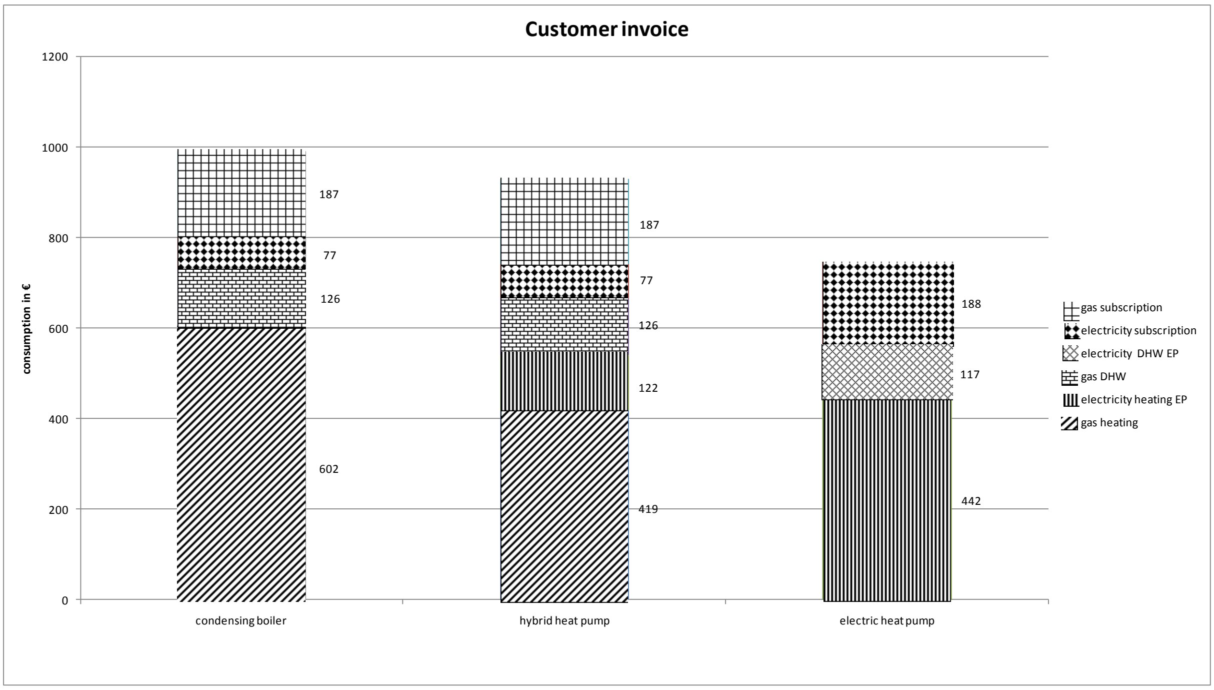


Figure 7: In a retrofitted house, the hybrid heat pump energy cost is between boiler and EHP.

All these figures show that the hybrid heat pump is interesting for new dwelling because it provides higher primary energy savings. In term of cost, the operating cost is between boiler an electric heat pump, which corresponds to the investment cost position too. The cost difference on the energy invoice is also less important in new dwelling than in retrofit housing.

3.3 Test on the second generation of prototype, to prepare the field tests with the pre series units.

The second generation prototype has been tested in the experimental house (figure 8 and 9) installed in the GDF SUEZ research division near Paris during one heating season.

Figure 8: Experimental house.

Figure 9: Prototype installed.

The prototype has been instrumented by several sensors. The objective was to test the reliability and to evaluate the control system only in heating mode. This instrumentation allows evaluating:

- Gas consumption.
- Electricity consumption.
- Capacity of the boiler.
- Capacity of the electric heat pump.
- Efficiency of this hybrid product.

These tests have shown down that:

- No failure was detected.
- Comfort temperature was provided.
- Even if no noise measurement have been realize, the level supported is similar to the noise of a boiler.
- Control system should be finalized to integrate the primary energy control strategy. Indeed, for this prototype, the first setting is that the heat pump stops working below 9°C.

As next step of development, ten instrumented field tests are planned. The instrumentation system is similar to the one used in the experimental house. The objective of these field tests is to evaluate the seasonal efficiency of this hybrid product. The first started at the beginning of 2011. The characteristics of this house are as follows:

- Retrofit house.
- Located near Paris.
- Area 120 m².
- Installed in the garage.

The duration of these field tests is two years. This first installation does not include the good control strategy based on primary energy, like it is the case in the experimental house. That is why the seasonal efficiency is not relevant in that case, but will be analyzed in the following field tests.

The manufacturer has planned to launch the marketing of this monobloc product in September 2011. Currently, the manufacturer is developing a new control system to produce the domestic hot water with the electric heat pump and the boiler. The tests will be realized in the GDF SUEZ climatic chamber in July 2011. This improvement will increase the efficiency of this system and the renewable energy part.

3.4 Next work : integrate the systems in regulations and standards and work on smart control

Currently, several actions are lead to integrate the hybrid heat pump on the French market first but also the European market.

The hybrid has to be integrated in the French thermal regulation 2012. GDF SUEZ is working on the drafting of a method allowing to simulate the hybrid heat pump.

Furthermore, as there is no standard today to test and compare hybrid heat pump, a French workshop has been created to determine a test protocol to evaluate the efficiency in standard conditions and calculate a seasonal efficiency. This work could be an opportunity to start a European work to write a standard dedicated to hybrid heat pumps.

Finally, as potential of this product, there is a work to do to have smart control of the system: indeed, for the energy provider, this product offers an interesting possibility to choose the energy as function of the energy short term prices. This represents a further development but a very promising field in term of commercial offer for the customer.

4 ABSORPTION HEAT PUMP DEDICATED TO RETROFITED HOUSING

4.1 A project of co-development between GDF SUEZ and ROBUR

The aim of the project is to develop an air/water Gas Absorption Heat Pump (GAHP) dedicated to retrofitted individual housing, for heating and Domestic Hot Water production.

A 38 kW version exists for collective housing and has proven the efficiency of the system. In excess of 6,000 units (in June 2011) are installed in Europe in collective or commercial buildings. This market is expanding now, and shows the interest to develop such a product adapted to the mass market, with the challenge to reduce the scale and to improve the efficiency.

An initial set of targets for possible products have been defined by GDF SUEZ based on a preliminary study about the French market. The values are summarized in the table below.

Type	Outdoor unit, air/water
Technology	Absorption heat pump Working fluid : NH_3, Absorbant : H_2O
Type of installation	Outside unit+ domestic hot water tank inside the house
Maximal water outlet temperature at full load	65°C
Thermal capacity at 7°C/50°C	18 kW
Thermal capacity at -7°C/65°C	12 kW
Gas Utilization Efficiency (GUE is the efficiency indicator = Heat production/gas consumption as defined in EN12309-2. (10)) on Net Calorifc value 7°C/50°C	1.57
Nominal electric consumption	0.4 kW
Capacity modulation	1/3
Function	Heating and domestic hot water production

Table 5: Technical targets for a residential product.

The first conceptual prototype has indicated in the first preliminary laboratory tests that very good results can be targeted.

4.2 Laboratory and Experimental House tests

4.2.1 The laboratory tests

Those tests have been realized on a initial prototype and have been used to :

- Acquire indications about the efficiency according to the current standard (EN 12 309-2), and check other efficiency targets.

- Provide initial indication about laboratory test protocols, to perform the test points required by the different efficiency calculation methods, at full load and partial load. This work will need to be completed and included in the revision of the EN12309-2, which is supposed to include this kind of test.
- Define some possible efficiency profiles for GAHP products. With this kind of profiles, GDF SUEZ has developed an initial simple model to estimate the annual efficiency that could achieve the systems depending on different parameters: ambient temperature, heating curve, and load profile.

4.3 Test in the experimental house

The conceptual prototype has been tested on an experimental house at GDF SUEZ R&D centre. This test is a half laboratory/half field test: the presence of the inhabitants in the real house is simulated. Furthermore, a normative scenario of domestic hot water demand has been used during this test. The house has been designed with enough radiators to obtain same heating load than a retrofitted house, particularly with 100% load in -7°C.

The results of the test have been analyzed by the manufacturer to benefit possible future research and development of the product and its control, with particular attention to partial load and defrosting strategies. It is anticipated that further development of the technology will be tested in the laboratory with similar approaches, to confirm that the units under development maintain the efficiency performance and reliability targets.

4.4 Calculation and estimation of seasonal efficiency

The seasonal efficiencies obtained on experimental house for heating and domestic hot water application, in net calorific value and in primary energy, are respectively 1,31 and 1,21. This result is very promising and can still be optimized with further development, for example on the flow rate strategy or defrosting control…

Furthermore, results of laboratory tests have been used to establish a simple model developed to estimate the seasonal efficiency. This model has been injected in the GDF SUEZ software OCSYGEN® to compare to other systems. It uses climate and structure parameters of retrofitted houses.

	Condensing boiler 25 kW	High Temperature electric heat pump 14 kW + elec. Back up	Absorption heat pump 18 kW
Heating needs (kWh/year)	12 373	12 373	12 373
DWH needs (kWh/year)	2 835	2 835	2 835
Heating consumption (kWh_{NCV}/year)	11463	5475	9514
DWH consumption (kWh_{NCV}/year)	2941	2558	1931
[Heating + DWH] efficiency (NCV)	1,06	*	1,33
[Heating + DWH] efficiency (elec.)	*	1,89	*
[Heating + DWH] efficiency (primary energy)	1,04	0,73	1,24
Primary energy consumption (KWh_{pe}/year/m^2shon)	**111**	**157**	**93**

Consumption Cost (€/year)	**839**	**912**	**702**

Table 6: Calculation results of efficiencies, consumption in energy and cost of 3 systems installed in a same retrofitted house.

Estimations presented above have been calculated by using OCSYGEN® with following assumptions:

- The retrofitted house is located in H1a RT2005 French climate zone (nearly north region).
- This surface is about 110 m2.
- His typology is a house type 1982-1988.
- There are 4 inhabitants.
- Domestic hot water demand is medium consumption and a balance between shower and bath.
- Cost of 1 kWh of gas (high calorific value) is about 5,24 cent€ and 12,84 cent€ for electricity according to the actual French pricing.

In a similar building, the calculation gives an efficiency of 1.33 when the measurement shows 1.31, what shows the consistency of the model. The results also show the influence of electric auxiliaries consumption (pumps, fan) of the system on primary energy efficiency (10% lower than NCV efficiency). So it is important to well optimize these consumption. This conceptual GAHP is more efficient than the high temperature electric heat pump and the condensing boiler in term of primary energy (93 $KWh_{pe}/year/m^2$ instead of respectively 157 and 111).

4.5 Further actions

Having provided a preliminary indication of the suitability of GAHP technology to the residential market, discussion on the next steps are being finalized to define the most effective way to bring the technology to the market. Therefore further research activity need to be completed, product development phase need to be carried out, optimization of components, control strategy, defrosting parameters/logic, definition of the “system integration” need to be achieved and additional assessment by means of laboratory and field tests need to be performed.

Time and speed of GAHP market launch in the residential market will depend on support and investments that this technology will gather in the next few years.

In term of standards, absorption heat pumps are already included in the French thermal regulation and in the Ecodesign scope (2), but the standard EN12309 is currently being revised in order to include all the data for these regulations.

5 CONCLUSIONS

The market needs are in a short term hybrid heat pumps manly dedicated to new dwellings. Concerning the monobloc unit development, the B prototype have shown the feasibility in term of compactness, noise and reliably. The next step is now to improve the control strategy and check it on the next field tests. The mathematical model elaborate to estimate the seasonal efficiency shows in a French cold climate, which is unfavorable for heat pump, that the efficiency gain compare to a, electric heat pump in primary energy is 17%. The field test will have to confirm this trend.

Concerning the first conceptual prototype of absorption heat pump dedicated to retrofitted houses, the different tests performed have shown a seasonal gas efficiency of 1.31 NCV, also in a cold climate, what represent a huge efficiency gain compare to an electric heat pump. The model developed to estimate the seasonal efficiency in a similar configuration shows an efficiency of 1.33, what is an example showing the reliability of the model. These results are very promising for the GAHP technology applied to existing houses.

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