WGCPARIS2015
WORLD GAS CONFERENCE
"GROWING TOGETHER TOWARDS A FRIENDLY PLANET"

26th World Gas Conference | 1-5 June 2015 | Paris, France

A new promising efficient hybrid boiler subjected to field tests in France

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Background

In the frame of strong regulation context (particularly in Europe) which pushes, among main targets, on a reduction of primary energy consumption, French thermal regulation (RT2012) imposes on the new houses market constraints that clearly contribute for emerging new gas efficient technologies. Among them, hybrid gas boilers (or hybrid heat pumps that correspond to quite the same product) constitute a good response to reduce the primary energy consumption.

In this context, GDF SUEZ and Atlantic collaborated together from first calculation works related to French thermal regulation and laboratory tests to finalization of the development and marketing of a new hybrid boiler invented by SIC, a subsidiary of Atlantic.

To this purpose, the recent support of GDF SUEZ in this product was put through an assessment of energy performance field testing in two new houses.

These field tests are intended to:

- Validate the energy performance of the product during a full heating season,
- Verify that the client's comfort is assured.

This paper presents the results of monitoring of these sites over the period from February 2013 to May 2014.

Hybrid boiler principle

The principle of a hybrid boiler (as known as hybrid heat pump) is not the same than bivalent system one. While bivalent system is only managed by the bivalent air temperature beyond which Electric Heat Pump (EHP) operates, hybrid system is driven by a smart system control which take into account the efficiencies of both technology (EHP and gas boiler).

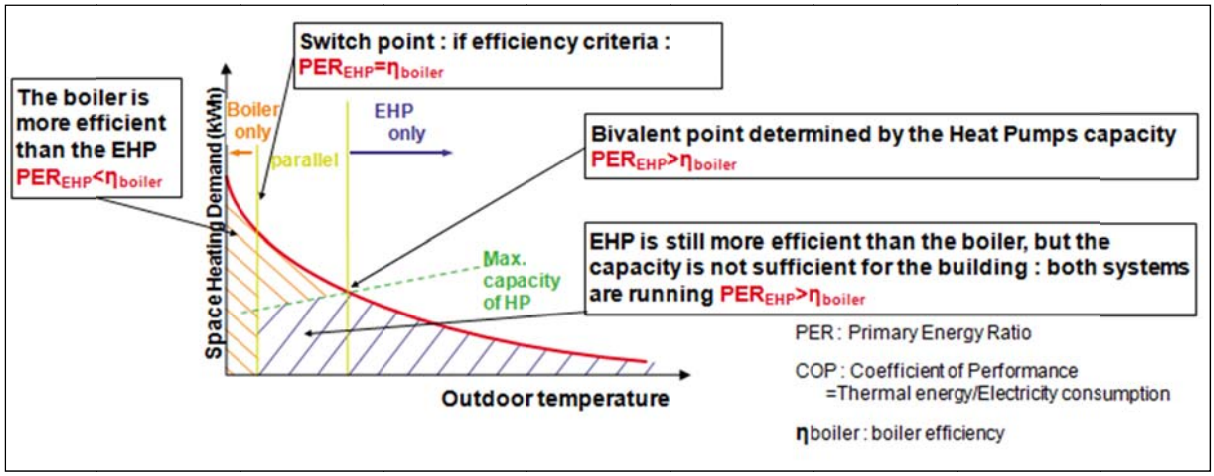

Figure 1 : Principle of a Hybrid boiler

EHP operates alone so such its capacity is higher than Space Heating Demand. Below this bivalent point, EHP operates with boiler only when EHP Primary Energy Ratio (PER_{EHP}) is higher than gas boiler efficiency (**η**boiler). If this criteria is not met, only gas boiler operates;

PER_{EHP} is calculated as follows:

$$PER_{EHP} = COP \times Prim_{ELEC}$$

Where :

COP = EHP Coefficient of Performance expressed in final energy

$Prim_{ELEC}$ = Primary energy factor for electricity, currently equal to 2.58 in France

The duo Hynéa hybrid boiler Atlantic gas is a bi-block system designed as follows:

- An outdoor unit integrating the compressor, evaporator fan which constitute a part of an 3kW electric heat pump,
- An indoor unit including the other part of the electric heat pump (condenser and valve expansion), a 24kW condensing boiler and a 120 liters Domestic Hot Water (DHW) tank.

These two units are connected by R410a refrigerant piping.

Figure 2 : Illustration of the ATLANTIC Hynéa Hybrid boiler

Methods

Two sites have been identified in late 2011 for the implementation and monitoring of real operating system performance.

Site	Type of house	Localisation	French Climatic area	Start of monitoring	DHW	Heating
1	New dwelling	Jebsheim (67)	H1b	February 2013	Integrated DHW tank	Space heating & LT radiator
2	New dwelling	Quimper (29)	H2a	January 2014	Integrated DHW tank	Space heating & LT radiator

Table 1 : Features of the identified field tests sites

Note : Site 2 is a pilot dwelling only occupied during one-off visits. Thus, conditions could be quite far from normal use.

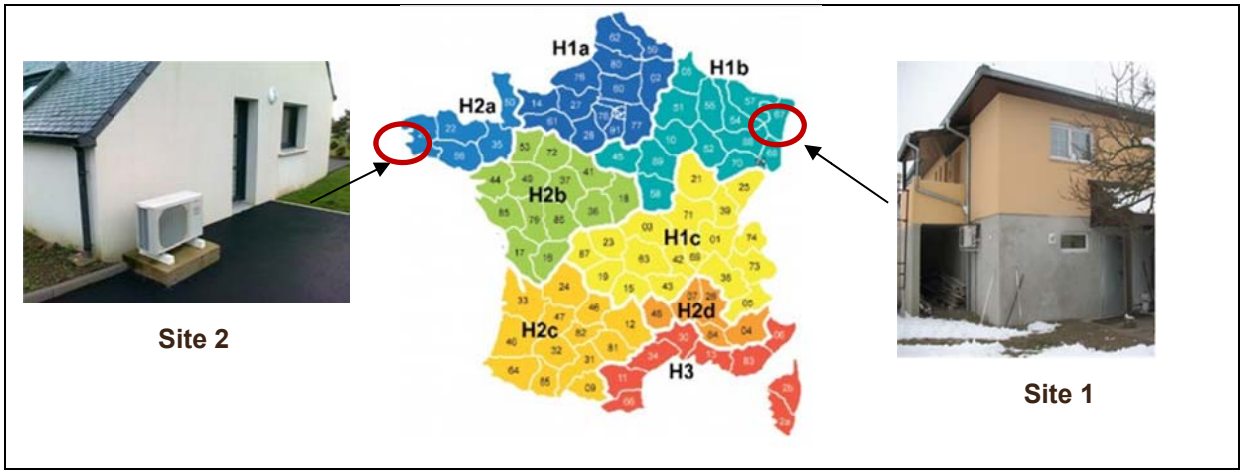

Figure 3 : Localisation of the field tests sites

Measurement means are same for both sites. Measured figures are positioned and listed as follows:

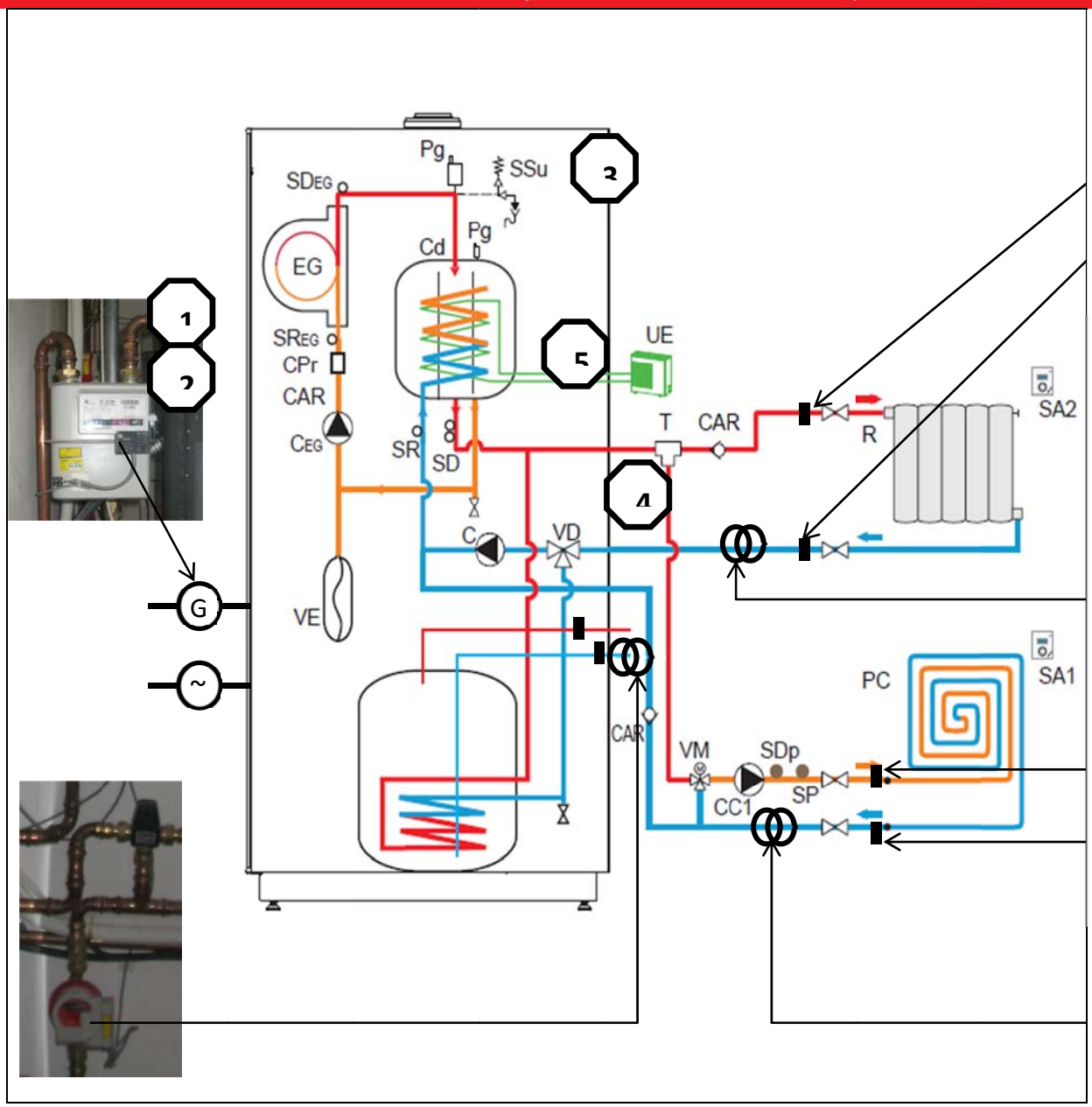

Figure 4 : Position of measured figures in field test sites

Position	Figure	Measurement means
1	Gas energy consumption	Gas meter

2	Electrical energy consumption	Electrical meter
3	Radiator useful energy	flow meter, temperature probes
4	Space heating useful energy	flow meter, temperature probes
5	DHW useful energy	flow meter, temperature probes

Table 2 : List of measured figures in field test sites

Note : Electrical meter measures the overall system consumptions (heat pump, gas boiler, auxiliaries).

Site 1 located in Alsace has been deployed since June 2012.

Site 2 located in Bretagne has been deployed since January 30th 2014.

Results

Site 1

This site has been deployed since June 2012 and partially instrumented (radiator circuit only) until February 2013 when space heating circuit was instrumented as well.

In DHW mode only consumptions have been analyzed.

2012-2013 Winter

The analysis covers the period from February to April 2013. During this period, the system in heating mode has mainly been analyzed according the following points :

- consumption of the Heat Pump (HP) only has not been calculated separately,
- end user was satisfied with both smooth functioning and comfort provided by the system,
- climatic conditions in this period was quite rigorous with average air temperature 4 to 6°C lower than the standard conditions,

Expressed in Primary Energy (PE), the energy performance of the hybrid boiler COP has fluctuated from 0.9 to 1.9 that reflects well Primary Energy control optimization of the system :

- COP(PE) reached around 1,00 when θ ext < 3°C ⇨ gas boiler assured the complete heating need,

- COP(PE) increased when θ ext > 3°C ⇨ gas boiler operated as back up.

In Heating mode, COP reached an average value of 1.16 in Primary Energy. This value is consistent to expected energy performances of these type of products.

During this season, the heat pump had run slightly for DHW preheating (confirmed during summer period).

The average boiler cycles duration has been around 15 minutes (48 minutes for HP) and the number of boiler starts have fluctuated from 15 to 36 per day (from 2 to 30 for HP).

Useful energy for heating is deployed as follows :

- 40% towards space heating with average water temperature around 27.5 °C
- 60% towards radiators with average water temperature around 32.5 °C

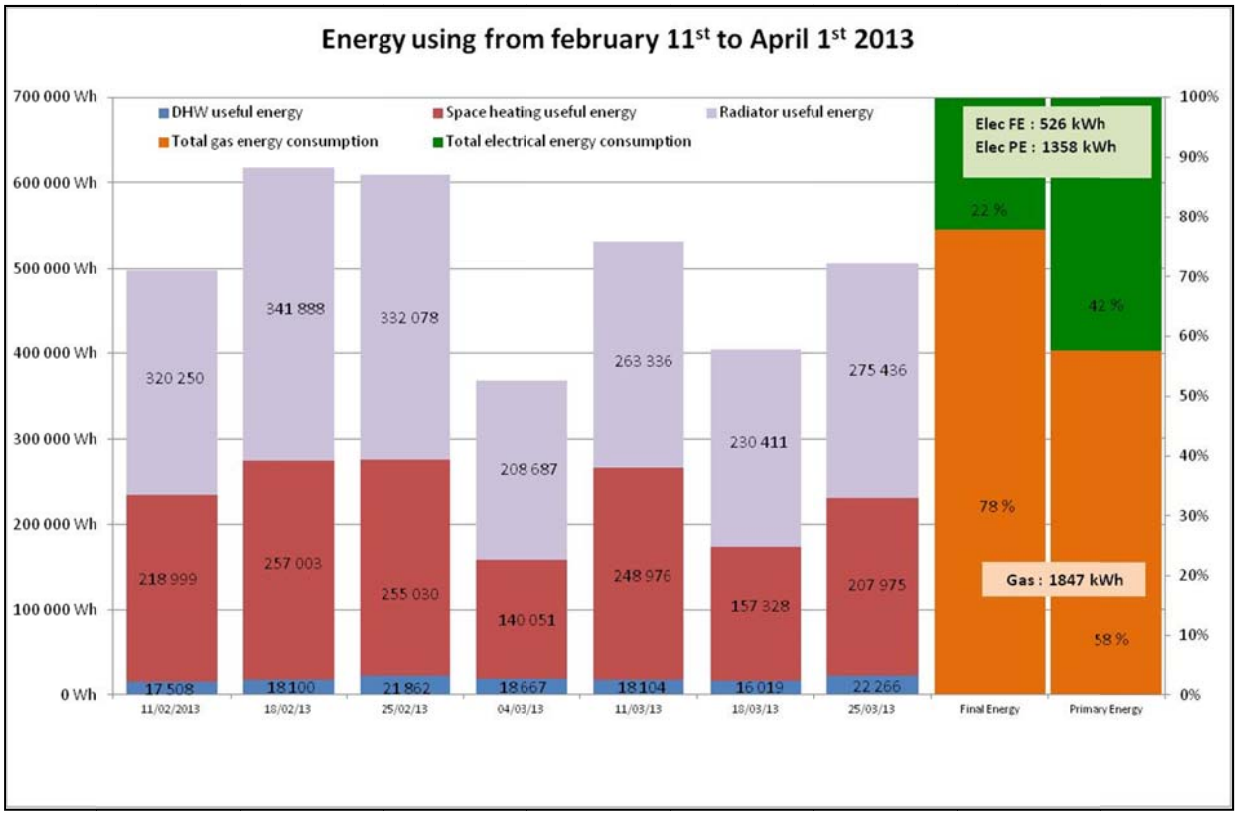

Figure 5 : Energy distribution during 2012-2013 winter in Site 1

Consumptions for heating are deployed as follows :

- Final Energy : gas/elec (78% / 22%)
- Primary Energy : gas/elec (58% / 42%)

Consumptions for DHW are deployed as follows :

- Final Energy : gas/elec (98% / 2%)
- Primary Energy : gas/elec (95% / 5%)

The electrical part dedicated to DHW includes auxiliaries in particular. These results show that HP barely contributes to DHW pre-heating.

2013-2014 Winter

The analysis covers the period from October to April 2014. During this period, the system in heating mode has mainly been analyzed according the following points :

- consumption of the HP only has not been calculated separately,
- end user was satisfied with both smooth functioning and comfort provided by the system,
- climatic conditions have particularly reflected a mild winter with average air temperatures 3 to 5°C higher than standard conditions.

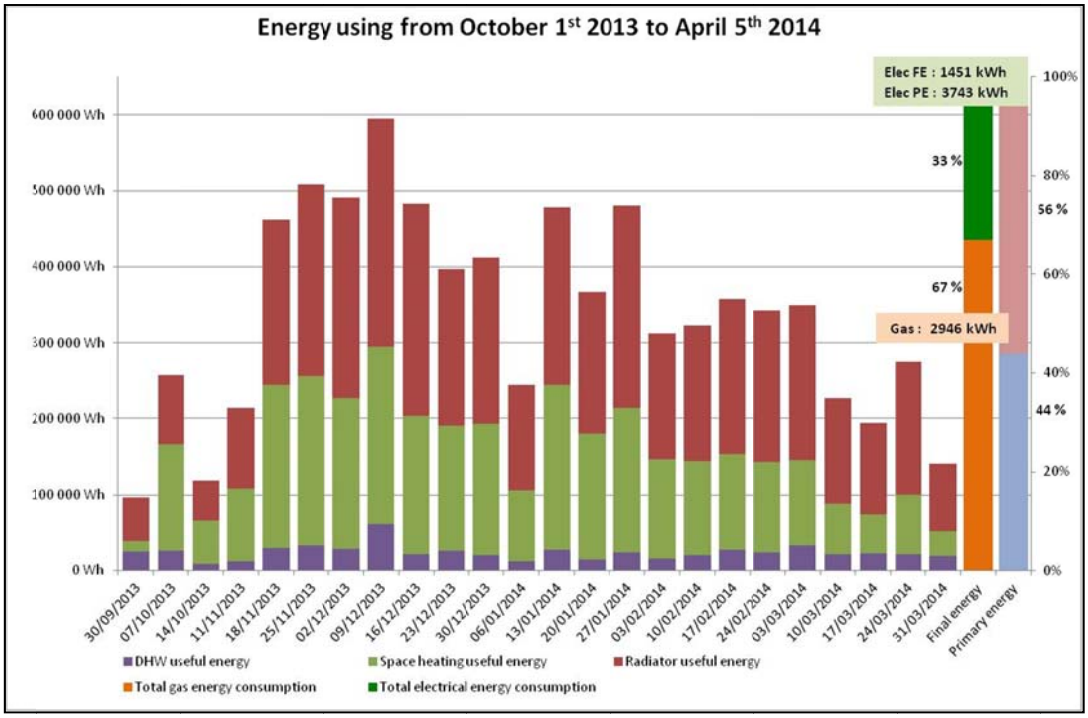

Figure 6 : Energy distribution during 2013-2014 winter in Site 1

During this second winter period, COP reached an average value of 1.41 in primary energy that is exceptional for this product. The reason is mainly due to the increase of the HP using thanks to the high air temperature trends.

Consumptions for heating are deployed as follows :

- Final Energy : gas/elec (67% / 33%) – (78% / 22% during previous winter)

- Primary Energy : gas/elec (44% / 56%) – (58% / 42% during previous winter)

Consumptions for DHW are deployed as follows :

- Final Energy : gas/elec (98% / 2%)
- Primary Energy : gas/elec (91% / 9%)

The average boiler cycles duration has been around 13 minutes (55 minutes for HP) and the number of boiler starts have fluctuated from 3 to 32 per day (from 0 to 33 for HP).

Useful energy for heating is deployed as follows :

- 43% towards space heating with average water temperature around 27°C
- 57% towards radiators with average water temperature around 32°C

2013 summer

This analysis is related to Avril-September 2013 period.

As already observed during winter, HP contribution to DHW is very marginal, even if there is no heating demand.

Consumptions for DHW are deployed as follows :

- Primary Energy : gas/elec (86% / 14%)
- Final Energy : gas/elec (94% / 6%)

Electrical part dedicated to DHW is more important during summertime but remains low. These data are consistent with manufacturer's choice, considering that efficiencies in heating mode are enough high to meet french thermal regulation requirement for new individual houses market (renewable energy mandatory criteria).

Consequently, manufacturer did not wish to increase more the use of HP for DHW production.

Regarding heating production during this period where temperatures are mild, HP covers predominantly the production as expected.

For example, in April, consumptions for heating are deployed as follows :

- Final Energy : gas/elec (26% / 74%)
- Primary Energy : gas/elec (12% / 88%)

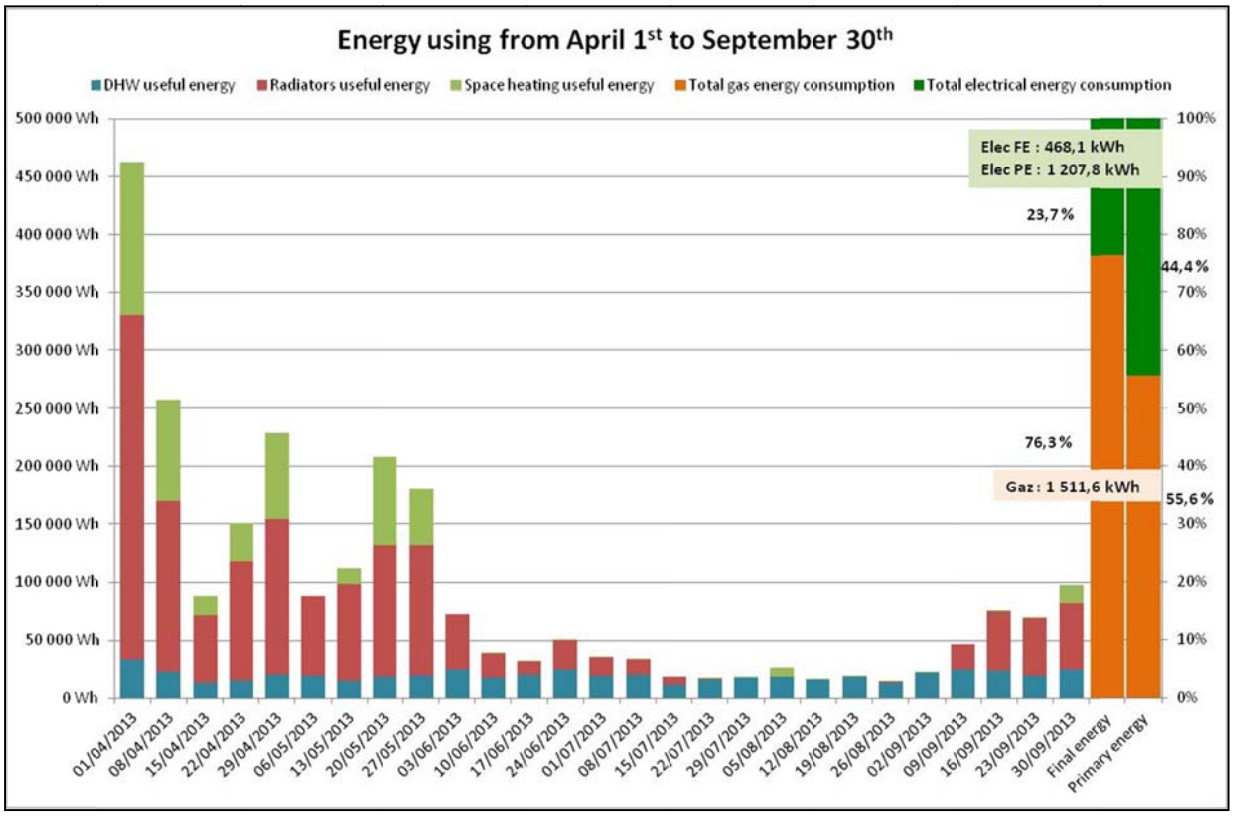

Figure 7 : Energy distribution during 2013 summer in Site 1

Site 2

This site has been deployed since January 30th 2014. This site is a pilot dwelling only occupied during one-off visits. As site N°1, there are two heating circuit (space heating and radiator). As unoccupied house, DHW energy consumptions have not been measured. Therefore, only heating mode has been analysed during monitoring winter period (from January 30th to April 5th 2014).

2013-2014 Winter

This analysis is related to January – April 2014 period.

As already observed in Site 1, climatic conditions have particularly reflected a mild winter with average air temperatures 2.5 to 4°C higher than standard conditions. During this second winter period, COP reached an average value of 1.47 in primary energy that is exceptional for this product

The average boiler cycles duration has been around 9 minutes (69 minutes for HP) and the number of boiler starts fluctuated from 0 to 8 per day (from 2 to 15 for HP).

Useful energy for heating is deployed as follows :

- 46% towards space heating with average water temperature around 26 °C
- 54% towards radiators with average water temperature around 29.5 °C

Consumptions for heating are deployed as follows :

- Final Energy : gas/elec (25% / 75%)
- Primary Energy : gas/elec (11% / 89%)

Summary & Conclusion

Seasonal performances in Heating mode for both site are higher than 1.00, reflecting well the optimisation of primary energy system control.

The results of monitoring of both Field Tests show good control optimization of Primary Energy in heating mode and confirm that the HP part of the system slightly participates in the DHW production.

Throughout the complete monitoring period, the two systems have shown hopeful performances in heating mode. Comfort conditions have been met and no anomalies were noted by the end user.

	Winter 2012-2013 (cold)	Summer 2013	Winter 2013-2014 (mild)
Average $COP_{(PE)}$ Heating mode	1.16	1.73	1.41 1.47
HP ratio in Heating mode (%)	42	88	56 89
Boiler ratio in Heating mode (%)	58	12	44 11
HP ratio in DHW mode (%)	5	14	8
Boiler ratio in DHW mode (%)	95	86	92
Average $COP_{(PE)}$ Heating & DHW mode	1.13	0.63	1.28

Table 3 : Summary of performances in sites 1 & 2

Performances on Primary Energy in heating mode are higher than 1.15 in H1b area and 1.20 in zone H2a at external temperatures near to standard seasonal conditions. They can also reach 1.40 (or 1.50) under mild conditions.

Site 1 in Alsace which has operated for 2 years, shows that the system is well perceived by the end-user. The comfort is well assure. Moreover, no anomaly was reported during the

monitoring period. Site 2 in Bretagne, although unoccupied, confirms the results obtained in Site 1.

These hopeful results confirm the consistency of the hybrid boiler on new French houses market. In addition, considering the easiness of installation, in particular for its wall mounting version, GDF SUEZ has given commercial product support to facilitate the market deployment.

Finally, 2015 shows very favorable circumstances on this deployment thanks to significant increase of hybrid system French sales rates in 2014 (2100 units) in comparison with 2013. That will certainly give it a successful start on the market.