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# Natural gas and renewable energy sources : combined solutions for current and future low consumption dwellings

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## ABSTRACT

Buildings worldwide account for 40% of the global energy consumption and its carbon footprint exceeds those of all transportation combined. Thus, setting this sector on the path toward low consumption is unavoidable to reach sustainability.

In France, dwellings built after 2012 will have, by law, to reach low consumption standard and incentives should allow more and more low consumption retrofittings. These standards are among the most demanding in Europe and technical solutions which allow to the buildings to reach these standards can be considered as “suitable solutions” for other temperate countries and not only for France.

This case study about new and retrofitted buildings in France sows that a combination of natural gas and renewable sources of energy are very suitable solutions to reach low consumption.

**Individual houses**

Low consumption standard for new or retrofitted individual houses can be reached by a complete thermal insulation, an efficient ventilation device and gas and renewable technologies :

- condensing boiler + ISH (individual solar water heater),

  or

- microCHP (combined heat and power plant) based on Stirling engine technologies.

**Collective dwellings**

Systems based on natural gas and renewables, combined with high thermal insulation and efficient ventilation device can allow new and retrofitted collective dwellings either heated by collective or individual systems to reach low consumption standards :

- collective heating systems :
  - collective condensing boiler + CSH (collective solar water heater) or photovoltaic device,

    or

  - collective absorption gas heat pump combined with collective condensing boiler,
- individual heating systems :
  - condensing boiler + solar water heater or photovoltaic device,

    or

  - microCHP.

**Towards 0 energy and positive energy buildings with natural gas and renewables**

New natural gas Fuel cells, already installed in Japan, are being optimized and developed for European market. With micro-CHP and photovoltaic devices they are the suitable solutions to build “positive energy” dwellings.

**A global approach for real energy savings**

Beyond the field of heating generator, researches are also leaded in the field of distribution, emission, regulation and energy recovery to decrease energy losses before use (insulation of distribution, new materials, etc.) or after use (drain water heat recover installed in the shower, etc.).

Moreover, final users are the most impacting agents for real energy savings. Thus, innovation in the field of energy savings has to take into account behaviours and sociology in buildings and devices designed by research centres must be of easy use and provide the comfort final users expect. Natural gas and renewables combinations do already take this comprehensive approach into account.

***C O N T E N T S***

# 1. ENERGY EFFICIENCY IN BUILDINGS : MULTIPLE OPPORTUNITIES FOR ONE BIG ISSUE

## 1.1. ISSUES AND OPPORTUNITIES

**Buildings worldwide account for 40% of the global energy consumption** and its carbon footprint exceeds those of all transportation combined.

Thus, **building is a key sector in the struggle against climate change** and large opportunities do exist in this sector to reduce its energy consumption and greenhouse gas emissions. Moreover, **technical solutions already exist to set building sector on the path toward sustainability**, (i.e. reducing by 75% its energy consumption and greenhouse gas emissions by 2050).

In France, the concepts of "**low consumption building", "zero net energy building" and "positive energy building" are being more and more applied** for new and retrofitted buildings. New dwellings built after 2012 will have, by law, to reach low consumption standard and incentives should allow more and more low consumption retrofittings.

## 1.2. LOW CONSUMPTION

The definition of "Low consumption dwellings" is different from a country to another, then we will define a **"low consumption dwelling" as a dwelling that roughly consumes 50% to 75% less energy than a standard building**, either new built or retrofitted. In France these buildings are defined as buildings with a consumption of primary energy for heating, domestic hot water, cooling, lighting and ventilation lower than :

- **50 kWhep/m².an for new dwellings** (in average, depending on climate zone),
- **80 kWhep/m².an for retrofitted dwellings** (in average, depending on climate zone).

**These standards are among the most demanding in Europe** and technical solutions which allow the buildings to reach these standards can be considered as "suitable solutions" for other temperate countries and not only for France.

## 1.3. NATURAL GAS AND RENEWABLES : ADEQUATE SOLUTIONS TO REACH LOW CONSUMPTION

Comprehensive studies about new and retrofitted low consumption buildings leaded by the Center for Research and Innovation in Natural Gas and New Energies (CRIGEN) of GDF SUEZ show that, **whether for new or existing, single or collective dwellings, low consumption standards can be reached by a combination of thermal insulation, efficient mechanical ventilation and efficient heating systems based on natural gas and renewables**. Moreover, innovative systems to reach "0 net energy" buildings are arriving on the market.

This case study on French new built and retrofitted dwellings will show the **huge opportunities to drastically lower energy consumption of buildings with existing technologies** based on natural gas and renewables. It emphasizes also on the fact that low energy consumption in buildings is not only a question of technical solutions but also and mainly a question of people : occupiers, architects, engineers, craftsmen, stake holders, etc. **: if the "human effect" is not taken into account, then no real energy savings will be made**.

# 2. MARKET SOLUTIONS TO REACH LOW CONSUMPTION STANDARDS

## 2.1. FROM REDUCTION OF NEEDS TO EFFICIENT SYSTEMS

Reaching low consumption standard requires a **global approach** with the combination of a **reduction of energy needs** and use of **efficient systems** that may include renewables.

The reduction of needs starts with a **"bioclimatic" architecture** that optimizes interactions between buildings and their environment, thus reduces heating and cooling needs, improving in the same way inhabitant comfort. Bioclimatic architecture tries for instance to maximize solar gains in winter by optimizing the glazing, while protecting the occupiers from overheating thanks to solarshades in summer and store and deliver heat by different cycling periods thanks to thermal inertia (**Figure 1**).

For retrofitted buildings the bioclimatic approach is tougher to follow than for new built dwellings, because it is not possible to change the global orientation of the house or the size of the windows. In this case at least solarshades can be installed, and it will be necessary to emphasize on inertia and ventilation.

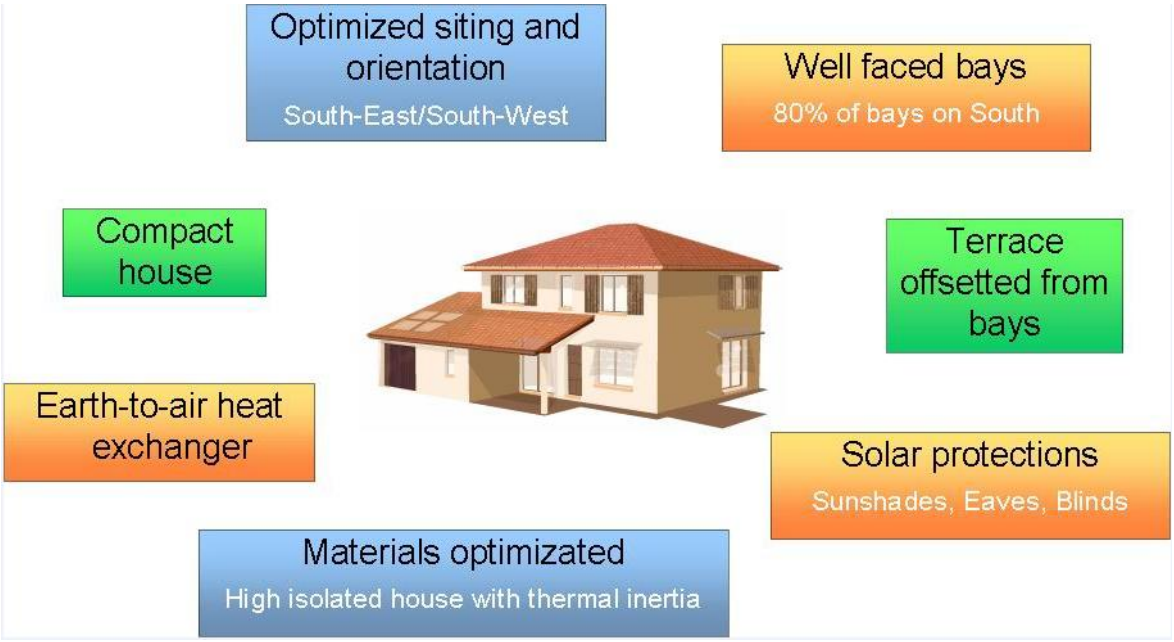


Figure 1 : An example of French traditional housing with bioclimatic approach

**A high thermal insulation** is also necessary and is part of the bioclimatic approach : roof, walls and floor shall be well insulated and ancient windows must be replaced by at least double-glazed windows. The kind of insulating material depends on the will of the owner (natural, low cost, etc.) but it is necessary to use certified material and to have a final high insulation coefficient reaching at least the levels shown in the table below.

| Minimal thermal insulation (m²K/W) | Roof | Walls | Floor |
|---|---|---|---|
| New building | 7 | 5 | 3 |
| Retrofitted building | 5 | 3 | 2 |

Figure 2 : Level of thermal insulation

The refurbishment is also going to reduce the amount of air "leaks" of the building (due to spaces between window and wall for instance). To allow the house (and its occupiers) to have a good inside air quality, it is **necessary to install an efficient ventilation device**.

*Nota bene : some people talk about "breathable" walls. But this does not mean that air is going through the wall and entering the house, it means that condensed water can go through the wall. Thus it is still compulsory to equip the building with an efficient ventilation device.*

Ventilation device can be either **extract continuous mechanical** ventilation or e**nergy recovery ventilator**. New built dwellings will mostly be equipped with the second devices while its installation is generally too difficult in existing buildings that will be equipped with continuous mechanical ventilation.

The next step consist in **equipping the dwelling with efficient systems**, especially natural gas systems described below.

As a matter of fact, **the scheme "bioclimatic approach → thermal insulation and ventilation → efficient systems" is the ideal pathway**. But, especially in retrofitted buildings, the **owner of the dwelling may not have sufficient budget to cover this scheme** and will have to choose between thermal insulation, efficient systems and ventilation. In this case, the main issue is to allow future energy savings. Thus, if a part of the frame, for instance the walls, is insulated, then it is necessary to insulate it at the highest possible level. But if there is no money to insulate all the frame and/or if the current energy generator fails, then it is smarter to replace this old device by an efficient new one based on natural gas.

CRIGEN is **leading tests in laboratories**, **field tests** and is in contact with many manufacturers of **condensing boilers, micro-CHP, solar** (thermal or photovoltaic) devices and **gas heat pumps**. Teams of engineers and technicians of CRIGEN are supporting industry with their know how to improve the performances of gas technologies. Results shown below are based on our experience and knowledge.

## 2.2. EFFICIENT DEVICES FOR INDIVIDUAL HOUSES

In France and in Europe, individual houses represent almost **60% of the global amount of dwellings**. Most of them are owned by individual owners with limited economical resources, with no crew to help them understand a technical device. It is compulsory then to offer technical **solutions that can be easily installed** by craftsmen, with **low investment**..

Space heating and hot water are the dominant energy uses. **Most of the houses are heated by natural gas boilers** or **direct electrical devices**. For these uses, natural gas and renewables offer different solutions to reach low consumption.

**For new built houses**, studies leaded at CRIGEN have shown that and **individual condensing boiler** with **an individual solar heater** (ISH) for hot water, complete insulation (roof, walls, floor) and efficient ventilation device allow to reach low consumption standard (see **Figure 3**).

**For retrofitted houses**, the same technical solutions can be installed. In some cases the architecture of the house will not allow to insulate it at high level and in some peculiar cases photovoltaic devices may be necessary to reach low consumption level (see **Figure 3**).

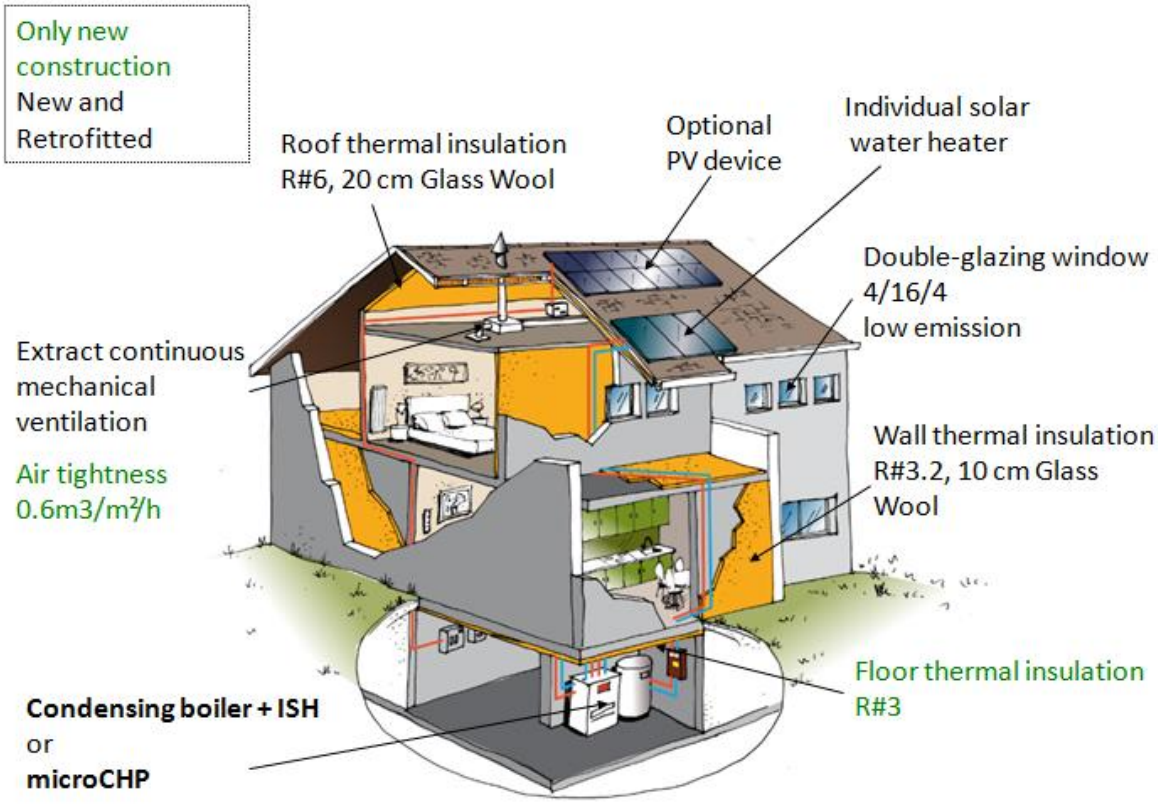


Figure 3 : Example of low consumption single house

**Condensing boiler** is a technology born is the 80's but from then it has been mainly modified and optimised. Nowadays, some condensing boilers are able to condensate even for the hot water production, allowing the **annual efficiency ratio to surpass 100%$_{ICV}$** ! Moreover, condensing boilers will more and more be able to adapt their power to the energy needs with modulating burners, and some can already cover a power range from1kW$_{th}$ to 10 kW$_{th}$ !

**Individual solar heater** is also born is the 80's. Modern solar heaters have a better efficiency and can be adapted to all type of houses. Their panels especially can be flat or tubular, depending on the available surface and the climate. In France, ISH with panel of 4m² and a water tank of 200l **can cover between 50% and 70% of the needs of hot water** of a single house with a four people family. ISH are becoming cheaper and more secure.

**Photovoltaic devices** are able to produce electricity using the sunlight, they are mainly based on semiconductors made with silicon. For a single house family in general 20m² are installed that generate around 2kWc of power (depending on the technology) or around 3000kWh of electricity in a year.

Some alternative technologies are arriving on the market like **micro combined heat and power** devices (micro-CHP). Micro-CHP is already affordable in many European countries and allow to **produce electricity at the same time as space heating or hot water**. Micro-CHP available on the market are equipped with a natural gas burner of 24kW$_{th}$ and a Stirling generator of 1kW$_{e}$. This kind of micro-CHP can produce about 2000kWh of electricity per year. **Low power gas heat pump** are also being designed by industrials and tested at CRIGEN. This technology will allow individual houses to be equipped with very high performance systems producing heat for space heating and hot water.

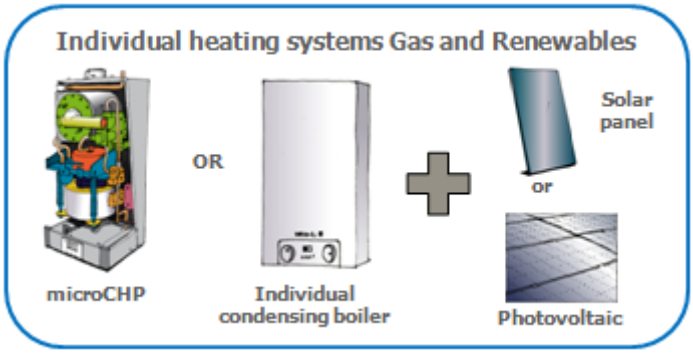


Figure 4 : Individual systems for low consumption dwellings based on Natural Gas and Renewables

## 2.3. EFFICIENT DEVICES FOR COLLECTIVE DWELLINGS

In France, collective dwellings account for 40% of the global amount of the dwellings. These dwellings are **mainly social housing**. Thus it is necessary to reduce energy bills of these buildings and owners are really interested in energy performance and efficient systems.

Collective dwellings can be heated by **individual or collective heating systems**. Studies leaded at CRIGEN show that a partial insulation (windows and roof for instance), efficient ventilation system and well known systems based on natural gas and renewable sources of energy can allow both of them to reach low consumption standards (**Figure 5**) :

- Collective heating systems :
  - collective condensing boiler + CSH (collective solar water heater) or photovoltaic device,
- individual heating systems :
  - condensing boiler + solar water heater or photovoltaic device.

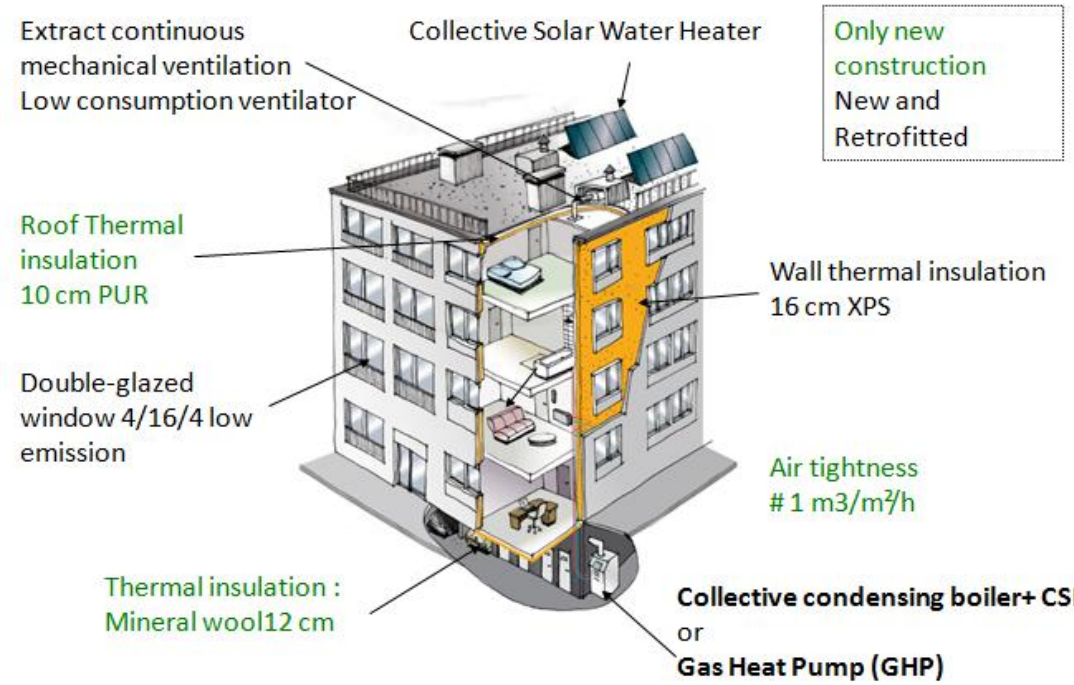


Figure 5 : example of low consumption collective dwellings with collective heating system

**Individual gas heating systems** are the same as for individual houses. The only difference can be found in the kind of boiler which is installed on the wall in apartment and mainly on the floor in houses.

**Collective condensing boiler** can reach the same performances as individual condensing boilers. The thermal power covers a range from some $kW_{th}$ to some $MW_{th}$. Then all the collective dwellings with collective heating system could be equipped with collective condensing boilers.

**Collective solar heater (CSH)** can be either all collective (panels and water tank) or partly collective (panels) and partly individual (tank and/or booster system). These systems can cover from **30% to 70% of the energy needs for hot water**.

And, as for individual houses, new technologies are arriving on the market such as **collective absorption gas heat pump** and **micro-CHP** that can be used as a collective device too :

- Collective heating systems :
  - **collective absorption gas heat pump** combined with collective condensing boiler, is a very efficient new generator based on a thermo-chemical compression of refrigerant using a gas burner. Its main advantage is that the heat coming from the burner can be used to improve its performance or to maintain a good power ratio when outside temperature is really low. Its efficiency ratio is around $170\%_{ICV}$.
  - **micro-CHP used as a collective generation system** (with condensing boilers) could be a very efficient way to use this kind of generator. As a matter of fact, the energy needs for heat and hot water of collective dwellings are more important and more steady than a the needs of a single dwelling. Thus, micro-CHP could be used as its top performance,
- individual heating systems :
  - **condensing boiler + solar water heater** or **photovoltaic device** : in this case the solar panels are collective and the tank is individual,
  - **micro-CHP** : the same solution as for individual houses.

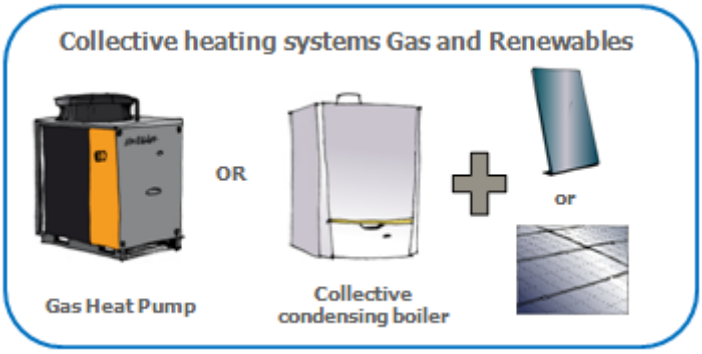


Figure 6 : Collective systems for low consumption dwellings based on Natural Gas and Renewables

# 3. TOWARDS 0 ENERGY AND POSITIVE ENERGY BUILDINGS WITH NATURAL GAS AND RENEWABLES

Technologies based on natural gas and renewables already allow any kind of residential building to reach low consumption standards. Moreover, technologies such as **microCHP** or **photovoltaic** set buildings on the track towards “0 net energy” or “positive energy”.

Nonetheless, **natural gas fuel cells**, already installed in Japan, are being optimized and developed for European market, they will allow to produce a higher amount of electricity than Stirling motors, fitting with new electrical needs in dwellings. As electricity demand is increasing

while demand for space heating and hot water should decrease in low consumption dwellings, fuel cells seem to be very well adapted.

CRIGEN is leading researches for these new energy technologies : **tests are in progress in our laboratories** and field tests will follow when the engineers and researchers teams will see that these technologies are reliable enough.

In the mean time, systems based on other energies are being developed like electrical high temperature heat pumps. Even if the performances of these systems are not very high yet, researches are being leaded and will increase the coefficient of performance. Then technologies based on natural gas must be improved as well and fit the demand of now consumption buildings and zero net energy buildings.

# 4. A GLOBAL APPROACH FOR REAL ENERGY SAVINGS

As shown in this paper, a **global technical approach is necessary** to reach low consumption standards. Talking about systems for heating and hot water, **generator** is always studied but researches are also leaded in the field of distribution, heat emission, regulation and **energy recovery** to decrease energy losses before use (insulation of distribution, new materials, etc.) or after use (drain water heat recover installed in the shower, etc.).

**Heat distribution** for space heating and hot water can account for **20% of the losses of heat of the system**. These losses are due to a lack of thermal insulation of the outdoor parts of the distribution circuit, electrical consumption of circulating pumps or a lack of hydraulic balancing. Thus heat distribution has to be **well designed** and **highly insulated**. Circulating pumps shall be calculated to fit the needs and shall be able to change their rotation speed.

**Heat emission and regulation** can also account for **15% of heat losses** because of inadequate radiators or a lack of thermal regulation devices. For a low consumption dwelling, emission systems must then **fit the needs** for space heating and **thermal regulation** device such as thermostatic valve and room thermostat shall be installed.

As people say, **the best energy is the energy which is not consumed**. A suitable way to reduce the energy need is to **recover it from the thermal losses** : extracted inside air or water used in the shower for instance. Then , low consumption dwellings may be equipped with energy recovery devices for ventilation and use the energy of greywater.

This **comprehensive technical approach is necessary but not sufficient** (**Figure 7**): **final users** are the most impacting agents for real energy savings. As a matter of fact, their impact on energy consumption can be **higher than 20%** (inadequate temperature setpoint, etc.). Thus, innovation in the field of energy savings has to take into account behaviours and sociology in buildings. Devices designed by research centres must be of **easy use** and **provide the comfort final users expect**. Natural gas and renewables combinations do already take this comprehensive approach into account.

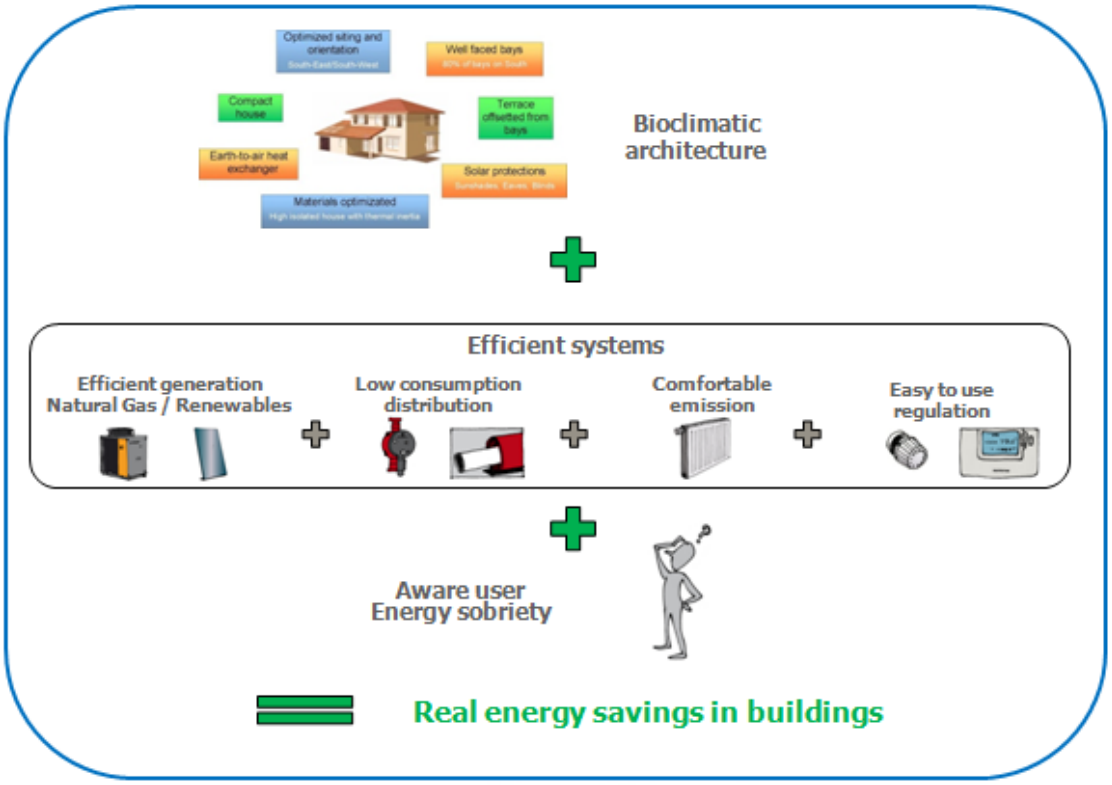


Figure 7 : Global approach of energy savings in buildings

In order to ensure real energy savings for final users, researches are being leaded at CRIGEN to **understand better their habits and behaviours**. They've already shown that final consumers are looking for better information in the field of energy performance and mainly about their own energy consumption. That is why CRIGEN is working on **smart metering** in buildings : devices allowing final consumers to know their consumptions and to control them are the first step toward real energy savings. The key aspect is to give the final user the right level of information (detailed enough but understandable by the user) and then allowing him to control its consumption and comfort with easy to use devices.

**Sustainable dwellings can be reached by a comprehensive approach including bioclimatic architecture, efficient devices and users behaviours, whether for new or retrofitted buildings. In the field of space heating and hot water, natural gas and renewables appear to be the right choice.**

# 5. REFERENCES

[1] WBCSD, “Energy efficiency in buildings – Transforming the market“, 2009
[2] Research and innovation division, GDF SUEZ, “How to define a “bioclimatic” construction?”, 2008

# 6. LIST OF FIGURES