Task 1: Market Overview

IEA-HPT Annex 45: Hybrid Heat Pumps

France

July 2016

Contents

1 Overview of the French Energy Sector

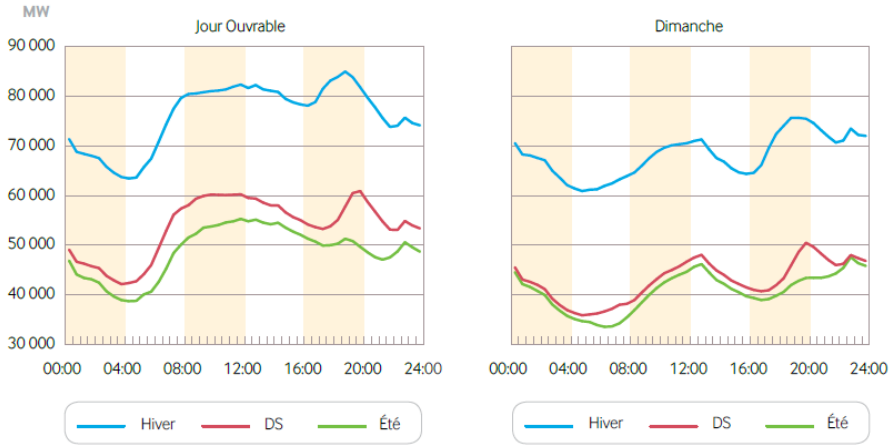
1.1 Overview of main challenges in France

Two main energy challenges in France can constitute drivers for a wide development of hybrid heat pumps.

The first challenge relies on the development of smart grids linked with the integration of renewables production.

Indeed, the important development of renewables for electricity production, in particular wind turbines and photovoltaic panels, initiated in the middle of 2000 in Europe generates a lot of changes in the organisation of the electric system. In particular, it progressively modifies the structure of the demand addressed to the classical centralized production means. Indeed, these renewable energy sources have today priority in the dispatch process. So as it may be, their zero variable operation cost would nevertheless insure them a very good position in the stack according to the merit order. As a result, the centralized production means have to satisfy the electrical demand minus the intermittent productions which is called “the net demand”.

Massive insertion of wind and photovoltaic generation will impact the net demand in two ways. On the one hand, it will reduce its average level; and on the other, it will increase its variability. However, the development of electrical uses, such as mobility, that would distort the demand is not taken into account in this analysis.



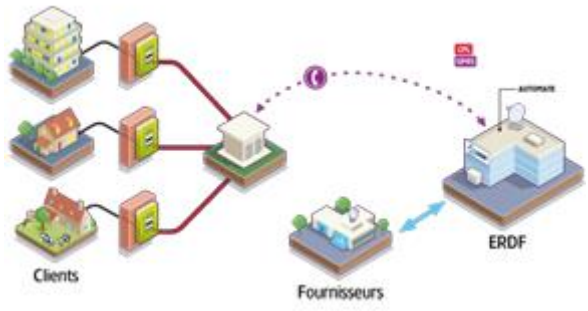
Typical daily demand profiles of week-days (on the left) and Sundays (on the right) in winter (blue curve), summer (green curve) and intermediate period (red curve) - RTE

The French electrical demand is characterized by a steep in the early morning (between 6h and 8h) due to the resume of domestic and economic activities followed by a slow rise till noon. Then it begins to slightly decrease till the next day except a first time around 19h due to tertiary and residential sector plus transport and another time around 23h because of the tariff structure. Eventually, the demand is modified by seasonal effects, mainly lighting and space heating. The actual thermal sensitivity reaches 2 300 MW/°C that explains the interest in load management and energy efficiency.

The reduction of the average level of the net demand will entail a decrease of the yearly running hours of both base and semi-base power plants. Moreover, the moments of very low net demand will be more difficult to forecast because they will also occur when the cumulated production of renewable generation is high.

The increase of the variability of the net demand will reinforce the needs of semi-base and peak power plants whereas the participation of wind and photovoltaic production to the peak is limited compared to their installed capacity. Within a day, the valley as well as the winter peak will no more take place at a fixed hour (19h). This increase of the variability as a global impact of renewable means of production make flexible devices, able to be off grid several hours per day, particularly interesting. The development of this type of appliances, including hybrid heat pumps, will allow a better management of the net demand.

In this context, the emergence of smart grids and smart meters is also a crucial point. In France, on the 28th September of 2011, authorities decided to generalize the deployment of smart meters for domestic customers and small professionals: 35 million units should be installed throughout the territory within the end of 2020. Linked to a supervision centre, these new generation meters interact permanently with the grid and contribute to make it smart by offering new possibilities in terms of load management, remote monitoring (including a better knowledge of the customers' consumption profiles) and innovative tariffs.



General scheme of the Linky infrastructure (source ERDF)

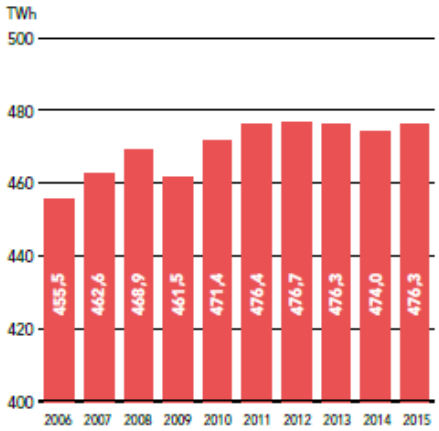
The second french energy challenge which can be adressed by the development of hybrid heat pumps is the objective of reduction of CO2 emissions and energy consumption in existing buildings stock.
The building sector, which represents 44.5% of the final energy consumption of France in 2012, is a major issue of the energy efficiency policies. The up-grading of the thermal performances of buildings is essential to reach the objectives in terms of energy efficiency, greenhouse gases reduction and renewable energy development. The targets are ambitious:

- generalizing the low consumption buildings for new constructions and positive energy buildings in 2020
- refurbishing 500 0000 old dwellings per year until 2017

To do this France adopted a range of diversified tools: regulations, financial incentives (fiscal and tax), training, information and awareness actions.
The **2012 thermal regulation** reinforces the requirements regarding the thermal performances of **new buildings**, starting from 2013: they may not consume more than **50 kWh of primary energy per square meter** for space and water heating, space cooling, ventilation and lighting. This reference value depends on climate zone, altitude, type of use of the building and the average area of housing. This is a significant tightening compared with previous legislation, which modulated the energy consumption allowance by type of heating system. This new regulation has strong impact on insulation requirements and guides strongly the space heating modes.
The **thermal regulation for retrofitted buildings** of less than 1000 m^2 is based on minimal performance requirements for installed or replaced equipments. It deals with equipments of insulation, space heating/cooling and hot water production. This is called the "element by element" thermal regulation. A modification of this RT is underway to make mandatory the inclusion of energy performance in case of extensive work on the building (e.g. facelift). In this regulatory framework, the development of hybrid heat pumps to replace old fossil boilers can be of great importance.

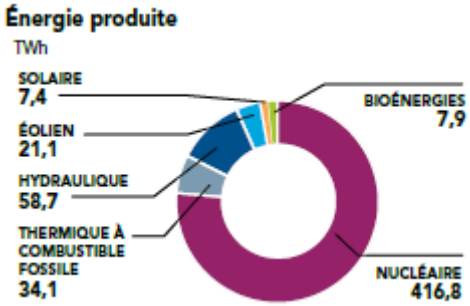
1.2 French electricity generation

The total electricity consumption was 476.3 TWh in France, in 2015. The evolution of the electricity consumption since 2006 is shown on figure below.



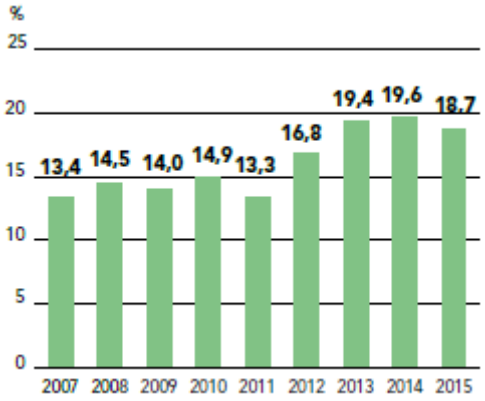
Evolution of french electricity consumption for the last 10 years

In the same time, the total electricity production was 546.0 TWh. This production was ensured by nuclear (416.8 TWh, 76.3%), fossil-fuel thermal (34.1 TWH, 6.2%), hydraulic (58.7 TWh, 10.8%), wind (21.1 TWh, 3.9%), solar (7.4 TWh, 1.4%) and bioenergy (7.9 TWh, 1.4%).



Electricity production in 2015

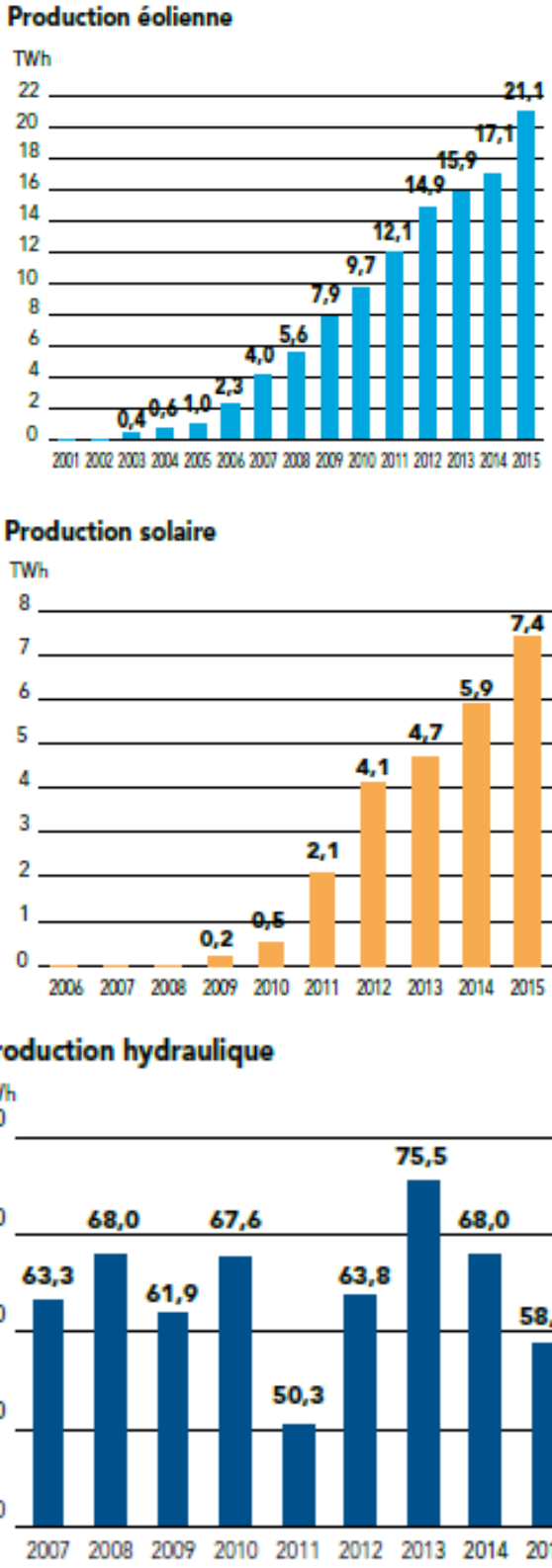
The share of renewables in the electricity production is 18.7% in 2015, almost stable for three years, as shown on figure 3. In 2015, the growth of wind and solar production (both +25% against 2014) doesn't compensate the decrease of hydraulic production (-14%), due to law rainfall. However, hydraulic still represents 61% of renewable electricity production in France. Share of wind production is about 24%



share of renewables in french electricity production

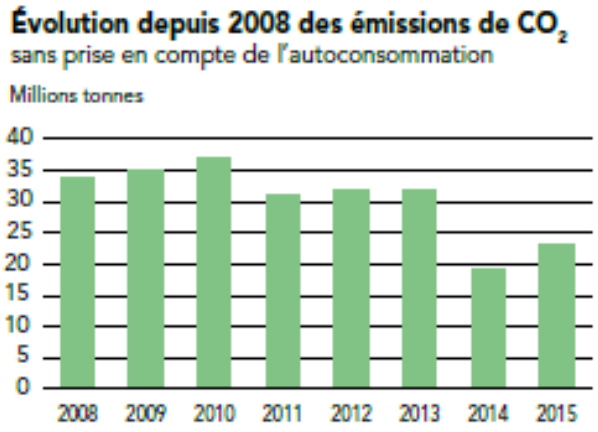
In 2015, the installed power of renewables increased by almost 2000 MW, mostly thanks to wind and solar developments. In the same time, the installed power of coal plants decreased by about 1500 MW.

The figure below represents the evolution over 15 years of renewables production (wind, solar and hydraulic) :



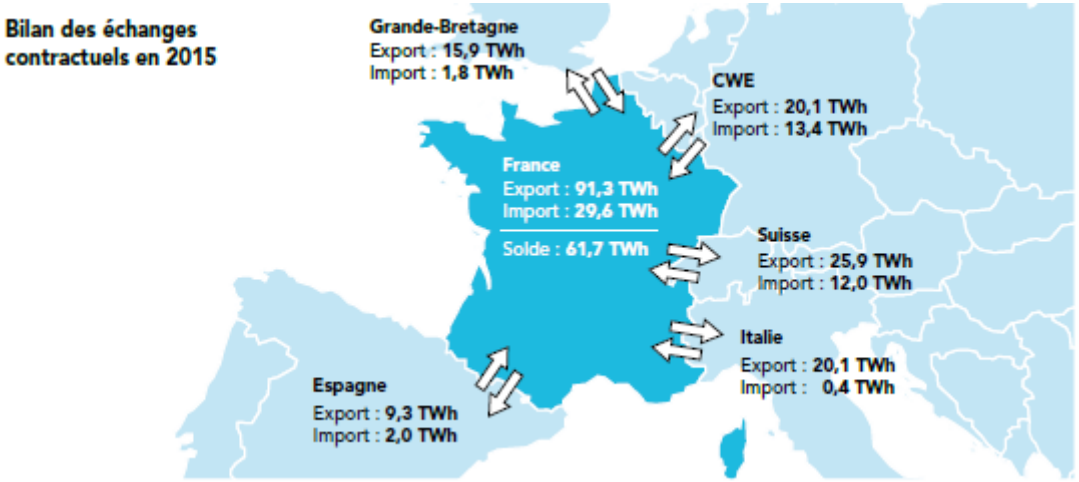
Renewables production in France (wind, solar, hydraulic)

This increase in renewables using induced a reduction of CO_2 emissions due to electricity production over years. However, the CO_2 emissions level increased in 2015, compared to 2014, due to a drop in hydraulic production induced by a lack of rainfall in France in 2015.



CO_2 emissions due to electricity production

French electricity export balance was +61.7 TWh in 2015. The main countries which are connected to French grid are shown below.

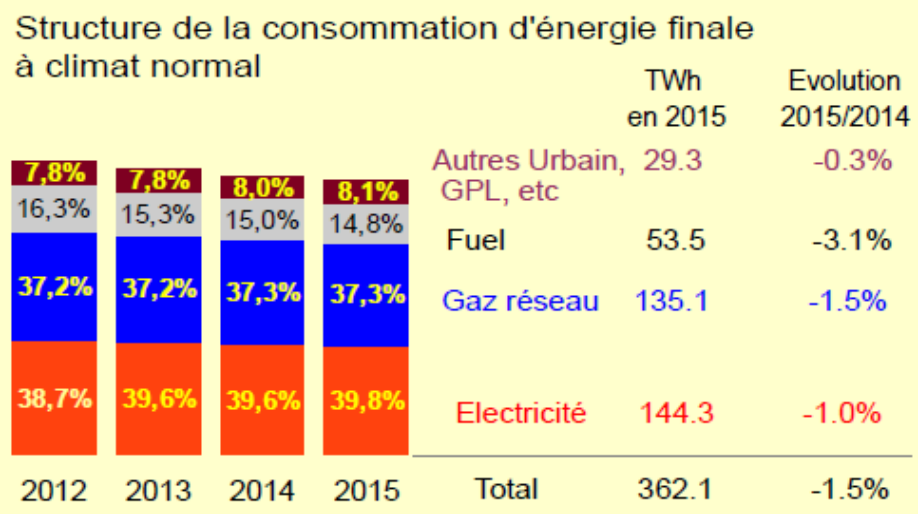


Import / export of electricity by France

1.3 French Energy Demand

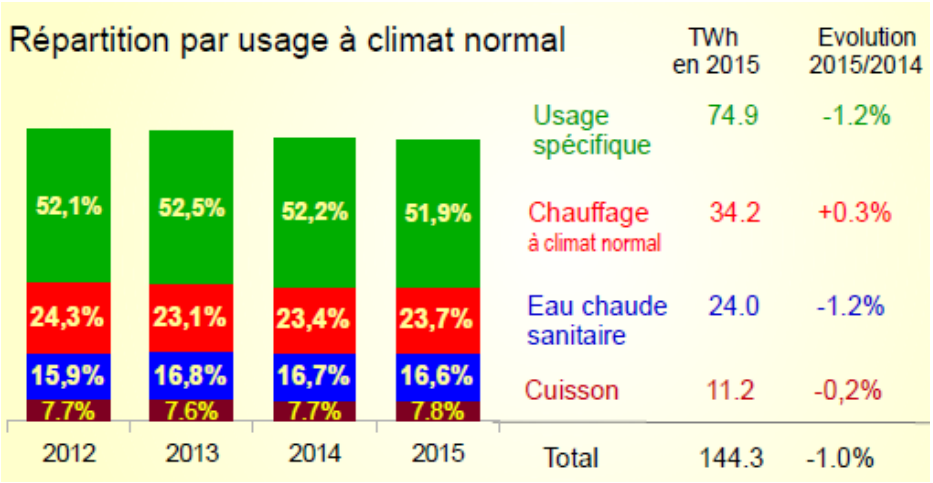
Domestic Sector

The French final energy demand in domestic sector has been slightly decreasing for several years, considering a normal climate. It represents about 362 TWh in normal climate, 357 TWh in real climate. The share of electricity is 39.8%, whereas gas and oil represent respectively 37.3% and 14.8% of this final energy demand (in normal climate).



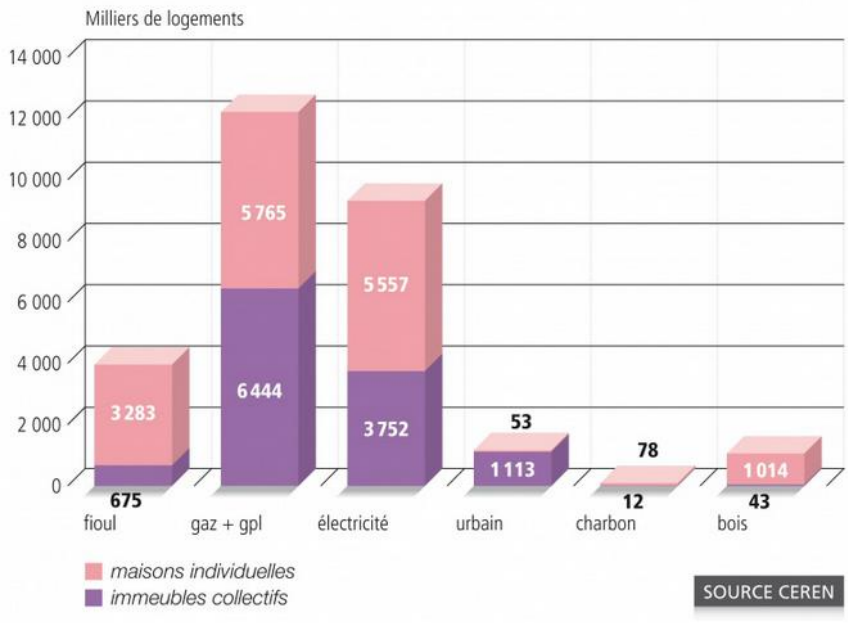
French final energy consumption in domestic sector

For electricity, the main application remains "specific uses" with almost 52%, followed by heating (23.7%) and domestic hot water (16.6%) purposes.



Uses of electricity in Frence domestic sector

For heating purpose, electricity is used in 36.1% of households in France, behind gas which is used in 40.8% of households. Oil is used for heating in 12.7% of French households.

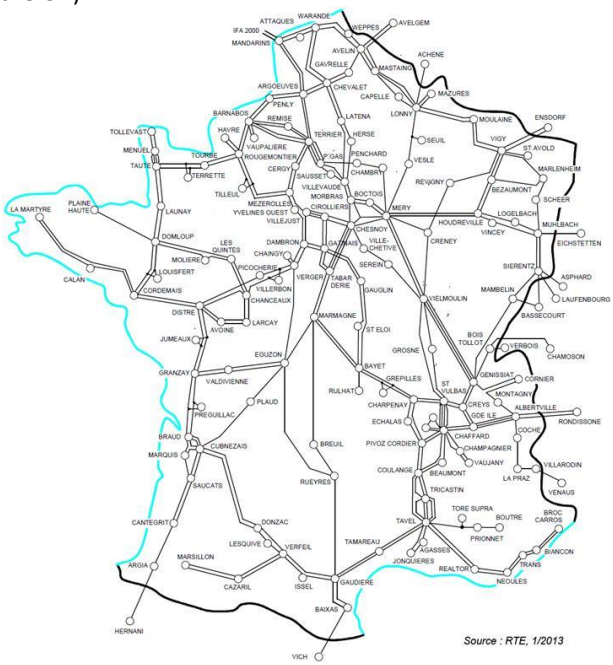


Share of energy sources for heating in French residential sector

1.4 French Energy Infrastructure

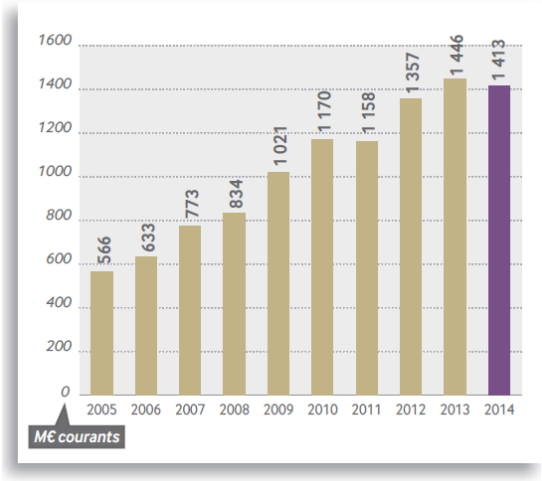
1.4.1 The French Electricity Grid

Transmission Grid: The electricity transmission network in France is owned and managed by **RTE**. 46 **interconnections lines** connect the French system to the neighbouring countries (Spain, Italy, Switzerland, Germany, Belgium, and the UK).



French electricity transmission grid showing the 400kV infrastructures (source: RTE)

The investments of RTE aim at meeting the challenges of the energy transition. The French electricity transmission network is in fact an essential link for receiving new productions (especially offshore farms), for the European energy integration (through the strengthening of cross-border trading capacities), for the safe operation of grids and the power quality.



Investments of RTE in millions of Euros (source RTE)

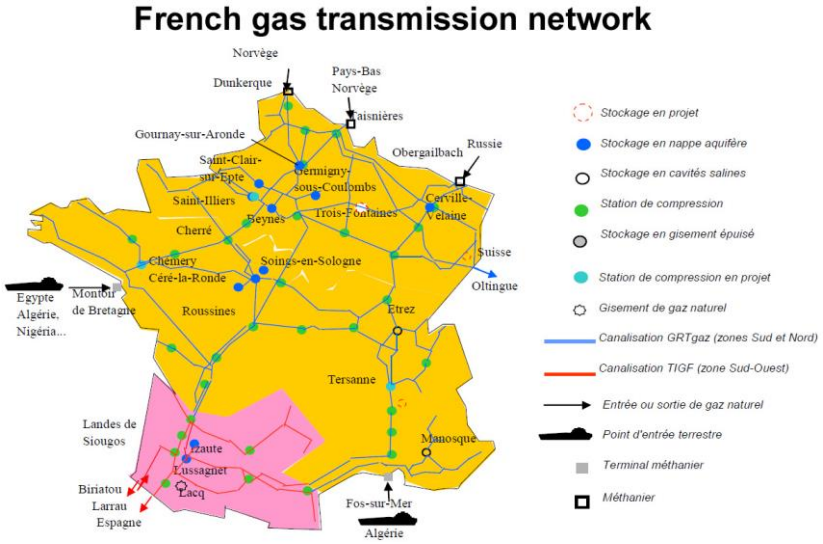
Its adaptation is based on the objectives of the Climate Air Environment regional schemes. When the hosting capacities are enough, a part per substation is reserved for renewable energies during 10 years. Otherwise, solutions of reinforcement or creation of power lines or substations are proposed.
Some oncoming projects are listed here-after:

- the France-Spain interconnection line (2000 MW, 320 kV) – 700 M€
- the upgrade of the electricity supply in the PACA region where local power generation covers less than half the demand and where a unique 400kV transmission line fulfils most of the consumer electricity needs – 170 M€
- the connection of offshore farms (6 000 MW by 2020)
- the France-Italy interconnection line

Distribution Grid: In France the distribution grid **belongs to local authorities** (municipalities), which delegate network operation to Distribution System Operators via **concession contracts**. There are about 150 distribution system operators, the most important one being ERDF (recently become ENEDIS) (it covers 95% of the French territory) [18]. 31.3 million homes are connected to the electricity grid [19].

1.4.2 The French Gas Grid

The French gas **transmission** network is shared between two operators: **GRTgaz** [20], for 80% of the country (in yellow on the following figure), and **TIGF** [21] for the South-West French region (in pink on the figure). This gas transmission network is interconnected with Spain, Switzerland, Germany and Belgium.



French gas transmission network (source: [6])

As for electricity, the **distribution** gas network **belongs to local authorities**, which delegate network operation to Distribution System Operators via **concession contracts**. There are about 30 gas distribution system operators, the most important one being GrDF [22]. 10.6 million homes are connected to the gas network [19].

1.5 French Energy Policy

Ultimately, will policy drive increase in penetration of inflexible / unpredictable generation such as wind, and/or growth in heat pumps?

The building sector, which represents 45% of the final energy consumption of France in 2013, is a major issue of the energy efficiency policies. The up-grading of the thermal performances of buildings is essential to reach the objectives in terms of energy efficiency, greenhouse gases reduction and renewable energy development. The targets are ambitious:

- generalizing the low consumption buildings in 2013 for new constructions and positive energy buildings in 2020
- refurbishing 500 0000 old dwellings per year until 2017

To do this France adopted a range of diversified tools: regulations, financial incentives (fiscal and tax), training, information and awareness actions.

1.5.1 Thermal Regulations

The **2012 thermal regulation** reinforces the requirements regarding the thermal performances of **new buildings**, starting from 2013: they may not consume more than **50 kWh of primary energy per square meter** for space and water heating, space cooling, ventilation and lighting. This reference value depends on climate zone, altitude, type of use of the building and the average area of housing. This is a significant tightening compared with previous legislation, which modulated the energy consumption allowance by type of heating system. This new regulation has strong impact on insulation requirements and guides strongly the space heating modes. In particular, the reference to primary energy without any consideration for CO_2 emission levels leads to promote indirectly gas boiler heating systems at the expense of electrical solutions (for which a conversion coefficient final/primary energy of 2.58 is applied). This aspect is partly offset by another rule included in this thermal regulation : among the energy consumed in a new built house, 5 kWh/m^2.yr have to come from renewables.

The **thermal regulation for retrofitted buildings** of less than 1000 m^2 is based on minimal performance requirements for installed or replaced equipments. It deals with equipments of insulation, space heating/cooling and hot water production. This is called the “element by element” thermal regulation. A modification of this RT is underway to make mandatory the inclusion of energy performance indicator for the new installed element.

1.5.2 High Energy Performance Label

A **label "high energy efficiency renovation"** was also created. It includes two levels for buildings dedicated to residential use: the label "high energy efficiency renovation, HPE 2009» for buildings reaching a primary energy consumption of less than 150 kWh$_{ep}$ / m² / year for the afore mentioned 5 uses and the label "low energy consumption building renovation, BBC 2009» for buildings reaching less than 80 kWhep / m² / year.

From January 2013, it is required to provide a certificate of inclusion of the RT delivered by a professional.

1.5.3 Incentive Schemes

Many **incentive schemes for individuals** have been implemented:

– The Energy Transition tax credit (CITE): From 2005 to 2015, the Sustainable Development Tax Credit (CIDD) allowed individuals to receive a tax credit for the purchase and installation of materials or equipment that are therotically the most efficient in terms of energy-saving or energy production from renewable sources (only in existing dwellings). More than 7 million homes have been renovated thanks to this measure. Since january 2016, this tax credit is called Energy Transition Tax Credit. This tax credit represents 30% of the material costs (installation costs non included) if the material is installed by a qualified installer (with a certificate) in a dwelling older than 2 years. Materials have to have minimum performances to be eligible for this

tax credit, corresponding to EcoDesign requirements+few percents. The only system generally excluded is the air-to-air heat pump, accused to be used for cooling application and then to increase consumption by adding a service.

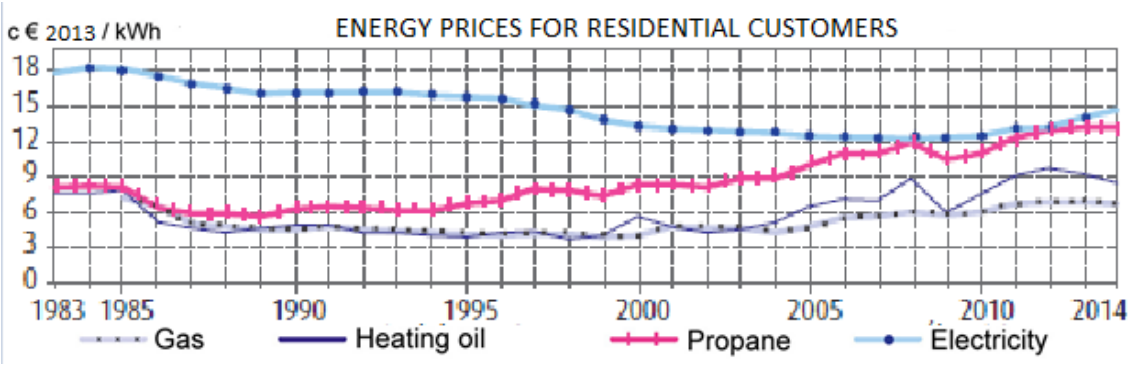
- The Eco-interest loan (eco-PTZ) is available from April 2009 and designed for individual homeowners or lenders to fund major renovation works. This loan finance up to 30 000 € improvements in energy efficiency of a home over a period of 10 years.
- The property tax exemption built: the amended Finance Act 2006 introduced the possibility for local authorities to exempt from property tax built for 5 years, with an exemption rate of 50 or 100%, constructions completed before January 1989 for which significant work to eligible CIDD has been made or constructions of new dwellings completed since January 2009 and bearing the low consumption building label.
- Reduced VAT rates for renovation: from January 2014, the energy renovation works of more than 2 years housings have a reduced VAT rate (5.5%). It concerns the work eligible for the tax credit Sustainable Development (CIDD).

1.5.4 Energy Savings Certificates

Created by the POPE law in 2005 [2], this mechanism encourages **energy suppliers** (suppliers of electricity, gas, fuel oil, and transport fuel from the second period) to **promote energy efficiency** to their customers by imposing a multi-year obligation of achieving energy savings. To fulfil its obligation, an energy supplier has to be an enabler of energy savings implementation (provided that this has an additional effect compared to business as usual actions). Certificates can be exchanged (bought and sold) between actors. All sectors are covered (residential, commercial, industrial, transportation, etc.), as far as all types of customers are covered (households, companies, public authorities, etc.). The major part of the actions performed is selected within a catalogue of **standardized operations** whose list is determined by ministerial order. At the end of the multi-year period and in case of failure to comply with their obligations, the suppliers must pay a penalty of 20 € per certificate. The unit used for the certificate is the "**MWh cumac**", which correspond to the **cumulated** energy savings brought by the action during its life duration, considering that the each yearly saving is **amortised** at a 4% ratio. The first period objective (2006-2009) was fixed at 54 TWh cumac (distributed among suppliers). For the second period (2010-2013), the objective has increased up to 345 TWh cumac, alongside with an extension of the list of energy suppliers concerned. An additional objective of 115 TWh cumac was fixed for 2014. For the third period (2015-2017), a total of 700 TWh cumac has been decided, with an additionnal amount of 150 TWh dedicated to fuel poor households.

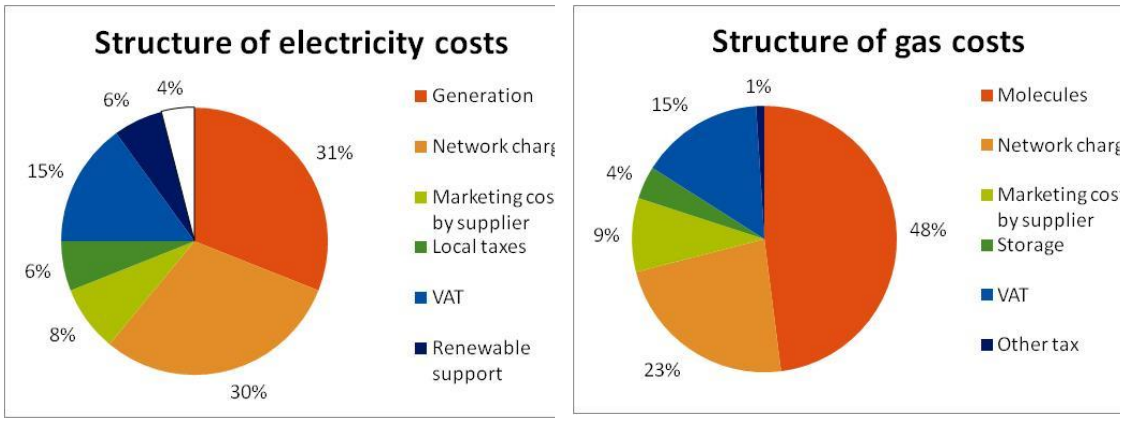
1.6 Energy Prices, Tariffs & Structures

During the last 30 years, **fossil fuel** prices for French residential customers have followed the **rising trend** of raw materials prices on international markets. Instead, the **electricity price**, due to the structure of the French mix and the large part of nuclear, has **decreased substantially** (in constant Euros) up to 2005. Since then, a new rising trend has begun, linked to the maintenance costs of the generation units and the new investments made to reinforce the networks.In the same time, the prices of gas and oil have begun to decrease.



Energy prices for French residential customers

The structure of the French **electricity costs** can be summed up as follows: the supply component counts for approx. a third, the network component for a second third, and taxes for the last third.
For the **gas costs**, the supply component counts approx. for a half, network and tax components representing a fourth each.



Indicative structure of electricity and gas costs - Tariffs for French residential customers (sources, DGEC [1] and CRE [19])

GAS TARIFFS

The customers have the choice between two types of offer : the reglemented one (with the “historical” supplier ENGIE, previously GDF SUEZ) and the market ones (with several suppliers).
Six pricing zones are defined in France, depending on the distance from the gas transport network (zone 1 covers the closest territories to the network, zone 6 the furthest ones) . The pricing zone influences the price of the kWh for gas consumptions higher than 6MWh/yr (heating application).

Consumption classes (kWh/an)	Yearly subscription €TTC	Price of kWh €TTC					
		Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Base (0 à 1000 - Cooking)	80.89	0.08510	0.08510	0.08510	0.08510	0.08510	0.08510
B0 (1000 à 6000 - Hot Water)	94.45	0.06830	0.06830	0.06830	0.06830	0.06830	0.06830
B1 (6 à 30000 - Heating)	237.87	0.04560	0.04640	0.04710	0.04780	0.04850	0.04920
B2i (30000 à 300000 - Heating)	237.87	0.04560	0.04640	0.04710	0.04780	0.04850	0.04920

Reglemented tariffs on june 2016, ENGIE

ELECTRICITY TARIFFS

Today, the consumer has the choice between two types of quotations: the regulated retail tariffs, offered only by the incumbent supplier (EDF) and the local incumbent suppliers (Electricité de Strasbourg) and market offers proposed by all suppliers (historical or not).
There are two types of regulated retail tariffs.

A first one with a flat rate:

Power level	Subscription (Euros/year)	Price (Euros/kWh)
3 kVA	54.45	0.1530
6 kVA	88.42	0.1530
9 kVA	117.20	0.1530
12 kVA	180.11	0.1530
15 kVA	206.57	0.1530
18 kVA	237.59	0.1530

A second one with day & night rates:

Power level	Subscription (Euros/year)	Peak price (Euros/kWh)	Off-peak price (Euros/kWh)
6 kVA	94.46	0.1636	0.1150
9 kVA	126.52	0.1636	0.1150
12 kVA	204.77	0.1636	0.1150
15 kVA	237.26	0.1636	0.1150
18 kVA	266.84	0.1636	0.1150

The customers benefit from a low price of electricity 8 hours per day, generally between 22 and 6 o'clock. These 8 hours are determined by the electricity distribution network operator and can be split in up to 3 periods. They cannot match with the national peak loads that occur from 8h to 11h and from 18h to 20h.

2 Current buildings and heating systems

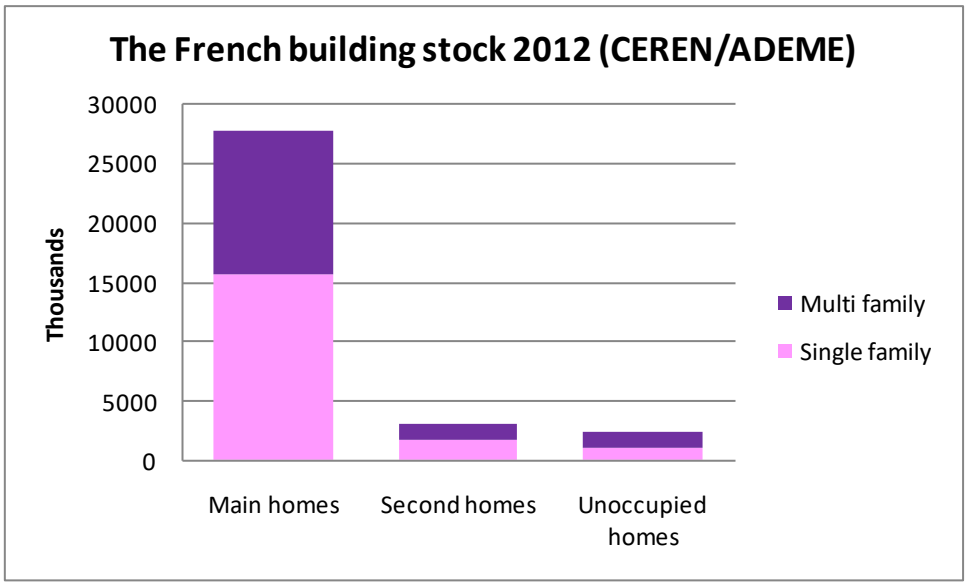
2.1 Overview of main challenges in France

The main challenge concerning French residential buildings lies on their environnemental impact : how can we reduce the final energy consumption of a very old building stock. Indeed, as said previously, about 60% of the dwellings had been built before 1975 (date of the first thermal regulation).

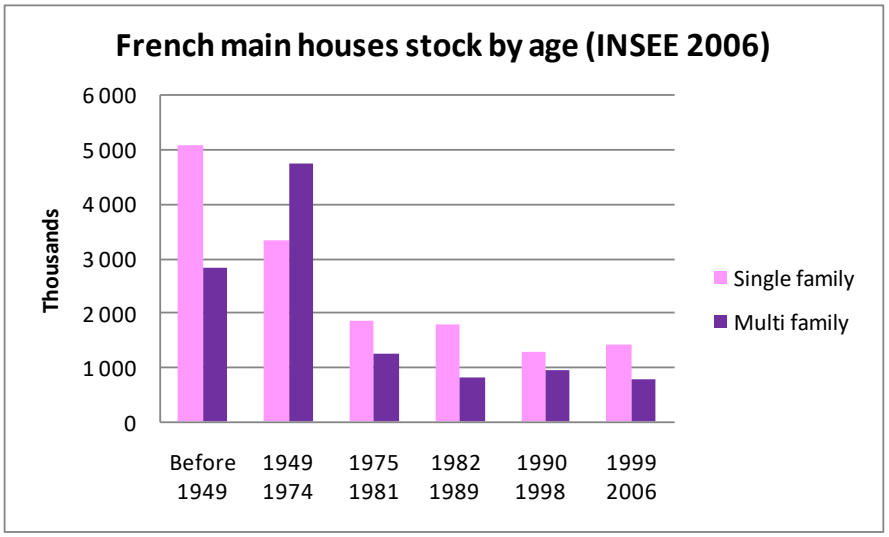
2.2 French Housing Stock Characteristics

DESCRIPTION OF THE BUILDING STOCK

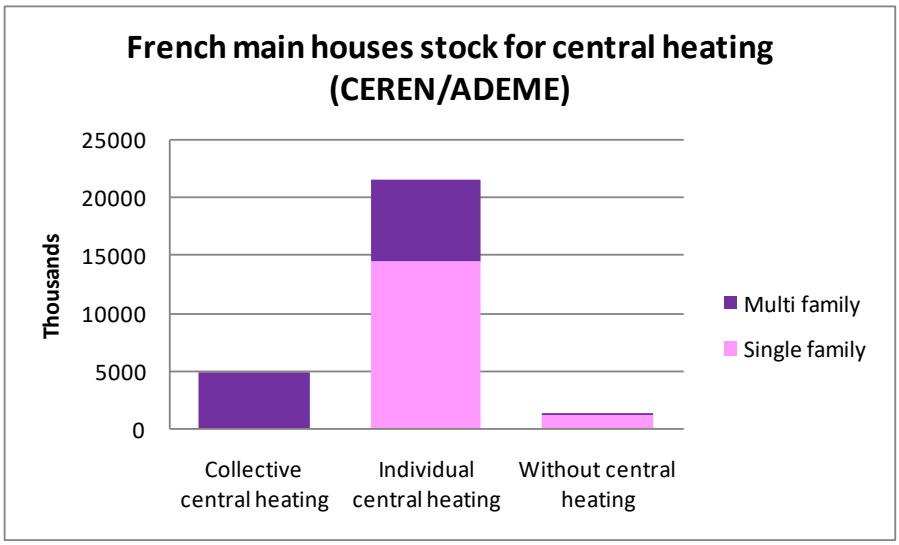
In 2012, France had 33.4 million residential buildings. Among these, 27.8 million were main homes, 3.2 million were second homes and 2.4 million were unoccupied.
If we consider the main homes only, 15.75 million are single-family homes whereas 12.04 million are multi-famly homes.



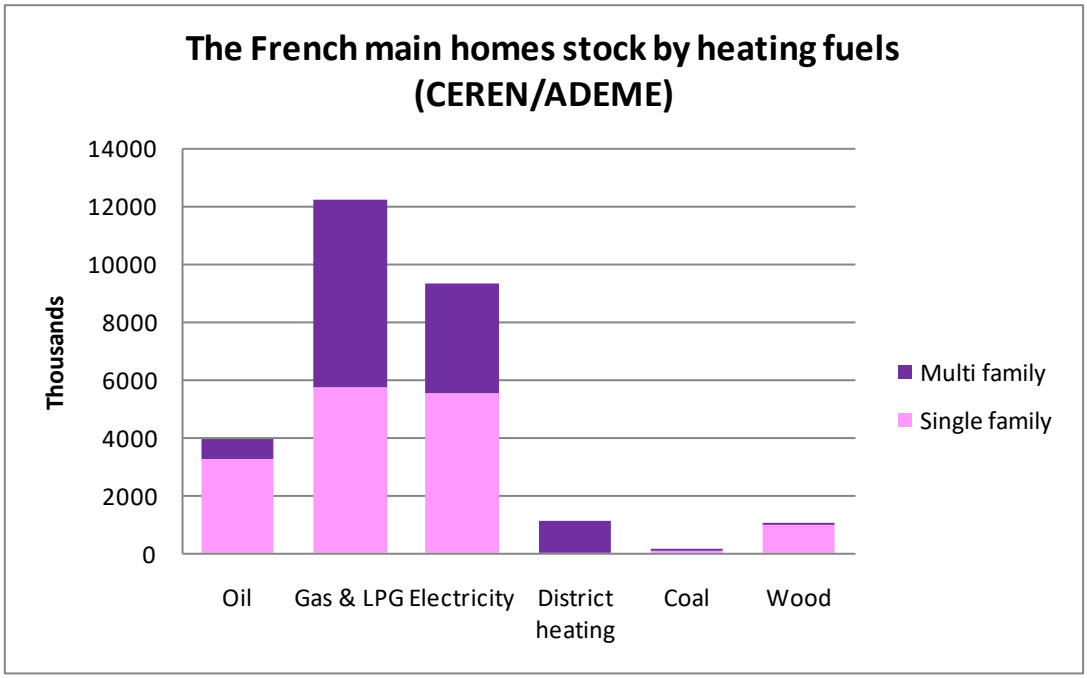
As precised before, the main houses stock was mainly built before the first thermal regulation (61% before 1975). The single family houses are the most numerous before 1949 whereas for the multi family houses it is between 1949 and 1974.



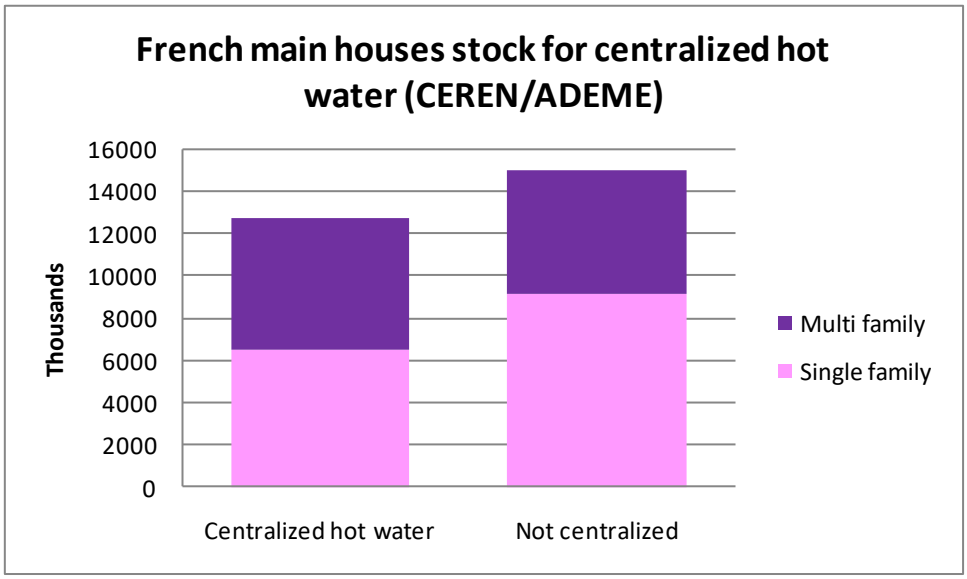
In 2012, 58.2% of the households are owner-occupiers, social housing and private renting representing respectively 17,1% and 22,0%.
Central heating is owned by 95% of the main houses. And collective heating represents about 18% for the multi family houses.



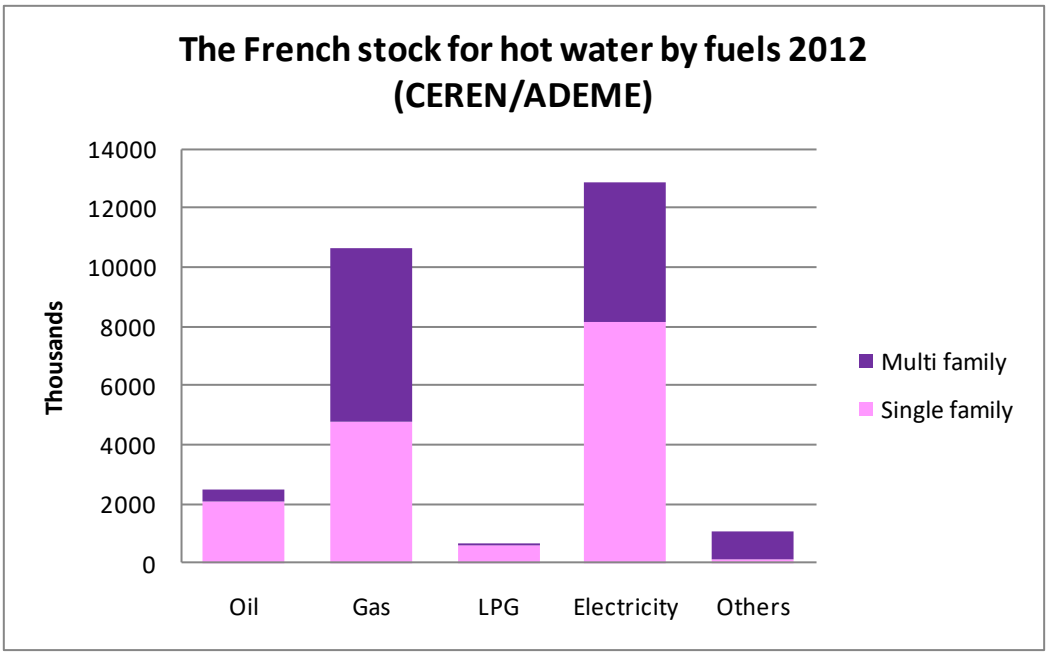
If we take a look at the fuel types used for heating, gas comes first with a 44% market share. Electricity is second with 33.5% of the heating systems oil is third with 14% but is mainly installed in single-family houses. District heating for flats is not negligible with 1.1 million households and so is the wood for houses with 1 million households concerned.



Centralized (the centralized heating system warms the water) hot water concerns nearly 46% of the main homes. For the multi-family houses, it reaches 51.4%.



For hot water, electricity is first with a 46.5% market share and even dominates for houses (51.9%). Gas comes second for the whole stock with 38.4% but is near half the stock for flats (48.8%).
For electricity, Joule effect with storage represents about 92% of the systems.

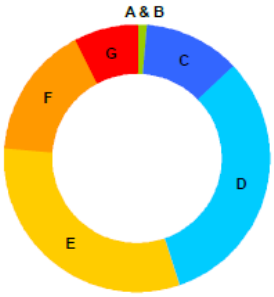


TYPICAL HOUSEHOLDS

The energy demand in households is strongly influenced by the last thermal regulation for new buildings. Therefore, it is useful to separate the description ef energy demand in some typical households in two main fields : existing and new buildings.

EXISTING HOUSEHOLDS

An existing household has an average (primary) energy consumption of about 270 kWh/m^2.yr. This average figure hides wide differences depending on the date of construction and the related thermal regulation (see figure below).

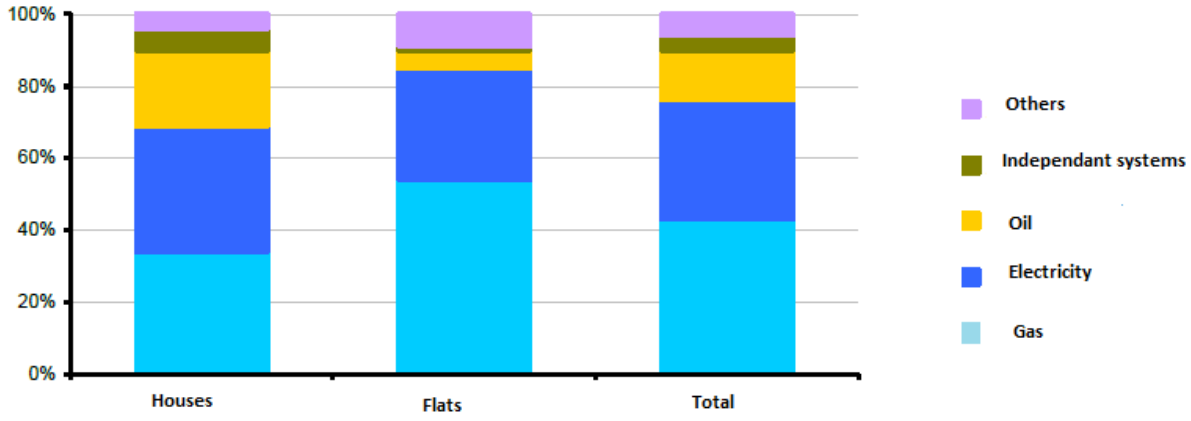


	Avant 1975	Après 1975	Après 2000	Ensemble
A (<50 kWh/m²/an)	0,03%	0,09%	0,20%	0,05%
B (51 à 90 kWh/m²/an)	0,61%	2,4%	5,0%	1,3%
C (91 à 150 kWh/m²/an)	7,4%	18,3%	27,9%	11,8%
D (151 à 230 kWh/m²/an)	27,5%	38,6%	43,9%	31,9%
E (231 à 330 kWh/m²/an)	32,2%	30,3%	20,3%	31,4%
F (331 à 450 kWh/m²/an)	21,1%	8,8%	2,4%	16,2%
G (>450 kWh/m²/an)	11,2%	1,6%	0,21%	7,4%
Total	**100%**	**100%**	**100%**	**100%**
Consommation moyenne (a)	301	224	187	270

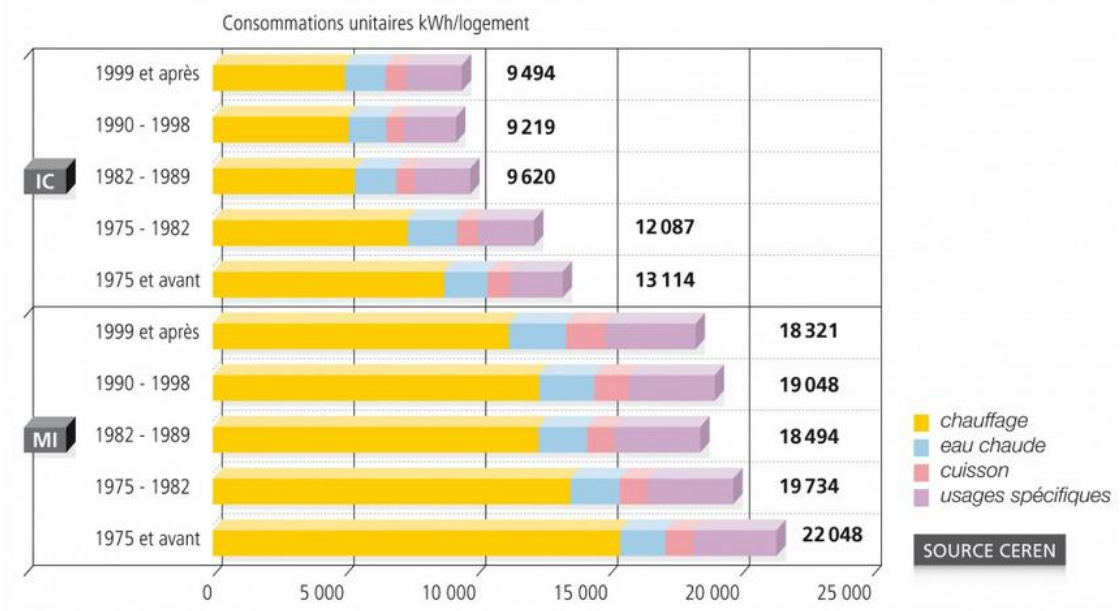
Unité : % du total de l'échantillon
Note : (a) = en kWh(ep)/m²/an

Average consumption (primary energy) of French existing buildings

These consumption figures include heating, domestic hot water, ventilation, lighting and eventually cooling applications and gather flats (average heated surface of 61 m^2) and individual houses (average heated surface of 105 m^2).
The heating and hot water energies used in existing dwellings are shown on the figure below. Oil or gas boilers equip about 60% of old dwellings.



The final energy demand in existing households is represented in kWh/household, for 2012, on the figure below. The final energy consumption depends on the construction date (related to the corresponding thermal regulation) for two cases : flats (IC) and individual houses (MI). The average parts of heating and DHWin the total consumption are respectively about 60% and 12% but decrease in recent buildings. The individual houses built before 1975 and the first thermal regulation represent about 60% of the building stock (of individual houses).



Final energy demand per household in France (2012)

NEW BUILT HOUSEHOLDS

The new built buildings have to follow the thermal regulation named RT2012 that imposes a ratio of primary energy consumption per year and m^2. This ratio is 50 kWh_ep/m^2.yr with a modulation depending on the climate. This figure takes into account heating, domestic hot water, ventilation, lighting and eventually cooling applications. As this regulation has been implemented on the 1st january 2013, real consumption figures are difficult to obtain. Common estimations for heating and DHW consumption ratiosfor a new built individual house are of 20-25 kWh_ep/m^2.yr and 15-18 kWh_ep/m^2.yr respectively. In 2013, heating systems installed in new dwellings were gas boilers (24%), heat pumps (35%), wood stoves (30%), Joule electricity (7%). Domestic hot water systems were heat pump water heaters (64%), solar water heaters (13%), double-service heat pumps (17%), condensing boilers (3%), hybrid boilers (3%). In 2015, heat pumps for heating represented about 50% of installed systems mainly at the expense of wood stoves.

2.3 Trends in the Heating Market

2.3.1 Energy Trends

The heating energy shares of the buildings stock evoluate very slightly over the last few years, as seen on the following figures (that concern only main residences).

Multi-family houses		2011	2012	2013	2014	2015
Collective central heating	urban	988,3	997,2	1006,2	1014,1	1025,9
	coal	10,6	10,6	10,6	10,6	10,5
	oil	646,9	614	578,6	545,8	528,7
	gas	2980,1	2973,8	2983,9	3010,4	3019,1
	others	76,3	88	98,3	107	115,4
	TOTAL	4702,2	4683,6	4677,6	4687,9	4699,6
Individual central heating	Coal-wood	3,3	3,3	4,2	5	5,8
	oil	64,3	60,1	55,5	53,3	49,6
	gas	3182,2	3214,3	3255,3	3290,9	3335,5
	LPG	24,2	19,3	16,2	14,2	11,9
	electricity	3631,4	3712,7	3779,5	3845,5	3870,3
	others	4,5	4,8	5,5	5,2	4,9
	TOTAL	6909,9	7014,5	7116,2	7214,1	7278
TOTAL		11612,1	11698,1	11793,8	11902	11977,6

Heating equipment in multifamily housing (in thousands of dwellings)

Individual houses		2011	2012	2013	2014	2015
Individual central heating	Coal	9,9	8,9	7,9	6,9	6,9
	wood	215,2	216,7	218,7	222,1	226
	oil	3149	3054,3	2973	2903,8	2841,6
	gas	5058,6	5084,6	5111,2	5126,4	5164,1
	LPG	427,2	404,1	393,8	383,9	378,3
	electricity	5332,7	5551,5	5742,9	5929,8	6047,9
	others	34	40,9	46,9	60	67,5
	TOTAL	14226,6	14361	14494,4	14632,9	14732,3
without central heating	Coal	65,2	63,7	62,4	61,9	61,2
	wood	919,2	927,3	948,2	956,9	960,6
	oil	137,1	134,9	132,6	131,6	130,2
	gas	18,4	17,4	17,1	17	16,8
	LPG	21,7	19	17,3	17,2	17
	electricity	176,5	179,5	181,4	184,4	185,2
	TOTAL	1338,1	1341,8	1359	1369	1371
TOTAL		15564,7	15702,8	15853,4	16001,9	16103,3

Heating equipment in individual houses (in thousands of dwellings)

2.3.2 Heating systems

In France, the key points on which forecasting studies on heating systems have been based the last few years were :

- Development of condensing gas boilers and heat pumps markets, due to new houses sector and the RT2012 thermal regulation
- Decreasing of oil boilers sales due to the rise of oil price and replacement of old oil boilers by gas boilers

- Development of wood stoves in combination with other systems (electric radiators or air-to-air heat pumps, for instance)

Two main events finally distorted the heating market results compared to the forecasts:

- The last two years, the number of new built houses was particularly low due to an unexpected continuation of the economical crisis
- The oil prices fell down instead of continuing to rise

Consequently, the trends are correct but the forecasted values of sales are over-estimated.
The case of boilers trend is presented below.

Boilers stock

In 2013, the stock of individual boilers was of almost 16 million units : 12.4 million gas boilers (79%) and 3.3 million oil boilers (21%). The stock of biomass boilers is still very low. About 3 million gas boilers and 1 million oil boilers are more than 15 years old.
In 2013, 12% of the installed boilers are condensing boilers (1.9 million units).

Boilers market

In 2013, some studies forecasted a global increasing of boilers market until 2018, for two main reasons:

- The expected development of condensing gas boilers in new individual houses
- The expected growing market for the replacement of old oil boilers in existing houses

These studies anticipated 620 000 gas and oil boilers sold in 2014, 655 000 in 2015 and 2016, 659 000 in 2017 and 665 000 in 2018.
These forecasts will have to be adjusted, taking in account the real figures for 2014 (579 000 units sold) and for 2015 (594 000).

2.4 Customer Preferences

The main trend identified in the customers behaviour is the “rebound effect” when an old unefficient heating system is replaced by a brand new and efficient one.
The energy savings are lower than expected due to a higher set point temperature when the heating system is efficient or the energy price low.

3 Market overview

3.1 Installed Heat Pump Capacity

The French Heat Pumps stock represents 1 900 000 units in individual houses and 260 000 Heat Pump Water Heaters in 2016 (source AFPAC).
The figure of 1900000 units considers only the heat pumps for heating purpose and excludes air-to-air units dedicated to cooling applications.
Among them, 1000000 units are connected to an hydronic distribution circuit (air-to-water or ground source heat pumps) and 900000 are air-to-air reversible units.
The average capacities are :

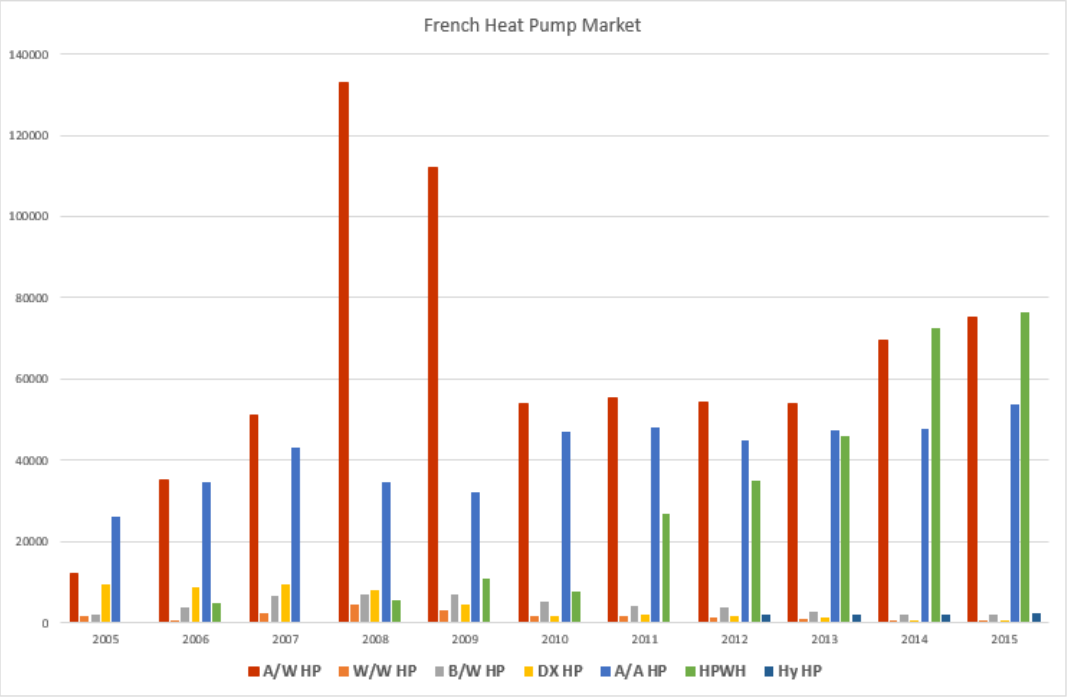
- air-to-water heat pumps = 11 kW
- ground-source heat pumps = 14 kW
- air-to-air heat pumps = 10 kW

3.2 Trends in the Heat Pump Market

The evolution of the French heat pump market over the 10 last years is shown on the figure below. This figure highlights several phenomena :

- In 2008-2009, the sudden increase of air-to-water sales due to the implementation of a new incentive (tax credit). In parallel, sales of air-to-air heat pumps, excluded from this incentive scheme, decreased.
- From 2010 to 2013, stagnation of sales at a low level due to the economical crisis. Air-to-air heat pumps sales are at a higher level due to summer heatwaves in 2011 and 2013 that accelerated sales of reversible products.
- In 2014-2015, a new moderate increase of sales, mainly air-to-water and air-to-air heat pumps, due to the implementation of the thermal regulation “RT2012” for new buildings which imposes a part of renewables.
- Since 2010, the development of heat pump water heaters, accelerated by the implementation of RT2012.
- The emergence of hybrid heat pumps the 4 last years

Nowadays, the French heat pumps sales are supported by the new individual houses market : in 2015 about 50% of new built houses were equipped with heat pumps.
However, we anticipated a growth of hybrid heat pumps sales on the retrofit individual houses market in replacement of old oil boilers in particular.



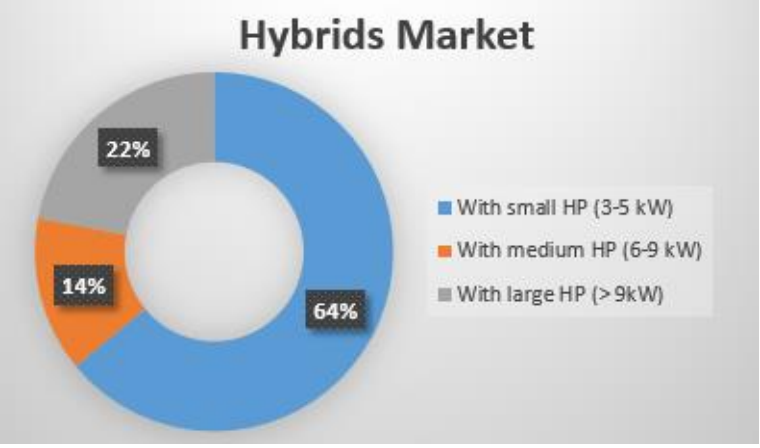
Sales of heat pumps in France over the last 10 years

3.3 Current hybrid products available

Three types of products, packaged ones, are available in France, depending on the dedicated market.

MARKET	HYBRID Products	
Replacement of oil boilers		HP : 4 to 16 kW Boiler : 25 to 35 kW ≈ 12 k€ installed
Replacement of gas boilers		HP : 5 to 16 kW Boiler : ~24 kW ≈ 10 k€ installed
New individual houses		HP : ~3 kW Boiler : ~24 kW ≈ 7 k€ installed Controlled with primary energy criteria

Nowadays, the main market for hybrid heat pumps is the new individual houses one in which the thermal regulation RT2012 imposes a part of renewables in the consumed energy. As shown in the table above, the hybrid products consist of a 3 kW heat pump and a gas boiler. Consequently, the hybrids sales are divided as shown on the figure below. The hybrid products with a small heat pump (3-5kW) are predominant.



Distribution of Hybrids sales in France

3.4 Market Drivers and Barriers for hybrids

Even if the new individual market is the main one, it remains limited because of competing technologies like {boiler+heat pump water heater} and {air-to-air HP+ HP water heater} combinations or double-services heat pumps.

The main potential for hybrids market growth lies in the replacement of oil or gas boilers in old non or bad-insulated houses. From there, several aspects can appear as drivers as well as barriers depending on their evolution.

Thermal regulation in small existing buildings (<1000 m^2) : a new version of this regulation is in progress. If it contains some important evolutions in terms of heating systems performances or renewables using, it can constitute an important driver for hybrids.

Oil prices : Obviously, the development of hybrids is greatly dependent on oil prices. The replacement of an oil boiler by an hybrid heat pump is profitable for the client in the short-term only if oil prices are high.

Industrials strategies : nowadays, hybrids manufacturers tend to develop products including small size HP to match the new built houses market. These products are not suitable for the replacement of oil boilers in existing houses, which need products with medium size HP in order to cover a great part of the heating needs. The wide development of such products at a reasonable price is a necessary condition for hybrids market growth in France.

4 Standards

As for other European countries, French energy related products have to deal with the EcoDesign Directive to be authorized on the market. For heating systems, this Directive imposes minimum annual performances, calculated in primary energy.

This Directive relies on associated European regulations (n°813/2013 for heating and heating/DHW systems) and several standards dedicated to calculation methods for annual performances or to test procedures.

For heat pumps, for heating or heating/DHW purposes, the standards are the following :

- Calculation method for annual performances : NF EN 14825
- Test procedures : NF EN 14511 (heating) and NF EN 16147 (DHW)

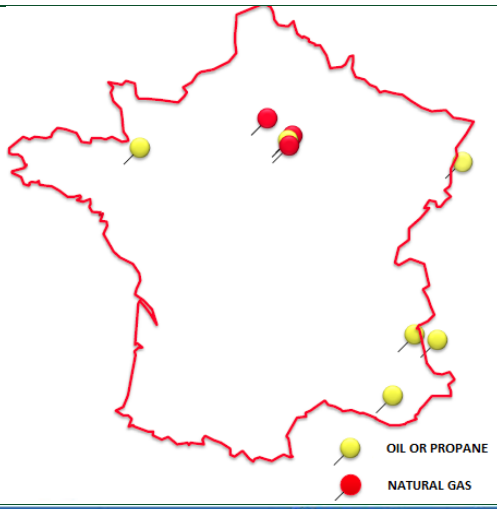
For boilers, the standards are the following :

- EN 15502-1 for gas boilers
- EN 304/ EN 15034 and EN 267 for oil boilers

Nowadays, hybrids are considered as heat pumps with a fuel (gas or oil) back up heater. On this basis, they have to comply with the NF EN 14825, taking in account a back up heater efficiency calculated thanks to dedicated standards. In other words, control strategies that optimize the coupling between the heat pump and the boiler are not taken in account. A review of the EN 14825 is in progress. This new version will probably consider the hybrid heat pump as a package including two generators and a controller.

5 Hybrid heat pump field trial projects

About 10 hybrid heat pumps are currently being tested in France. The localisation of these field test projects is shown on the adjacent figure.
Several types of hybrids (gas or oil, 2kW to 14 kW heat pump capacities) are tested in various climatic conditions.
Some sites data are given below. The results in terms of performances are not available yet.



Data site	Le Perray en Yvelines	Waldighoffen	Marseille	Puiseaux	Veneux les sablons	Samois sur Seine
						
Occupants	2	4	2	3	1	2+2
construction	1985	1996	1975	1995	1900 + 1980	1989
Heated Surface (m²)	90	116	180	96	110	150
Replaced system				Gas boiler 24kW	Gas boiler 23kW	Oil boiler 20 – 40 kW
Emitters	Steel radiators	Heating floor + radiators	Steel radiators	Steel radiators	Steel radiators	Steel radiators
Initial consumption (kWh)	17000	21000		12000	29000	20000
Hybrid HP	**Gas**	**Propane**	**Propane**	**Gas**	**Gas**	**Oil**

						
Instal.	20/10/2013	10/ 2013	01/10/2011	27/12/2012	21/02/2013	08/02/2013
Type	Split / Low Temp.	Split / Condensing	One-piece Ext. / Condensing	One-piece Int. / Condensing	One-piece Ext. / Condensing	Split / Low Temp.
Power(kW)	HP 10 Boiler 25	HP 4,4 Boiler 30	HP 5 Boiler 30	HP 2 Boiler 24	HP 3 Boiler 27	HP 13 Boiler 25
COP 7/35	4,04	5,04	4	3,4	4	3,86
HP on	Text adjustable: -25/ +35	COP> (elec cost / gas cost) or Text>-3°C & COP>2,58	COP> (elec cost / gas cost) or COP > 2,58	Text>3°C & COP>2,58	COP(elec cost / gas cost) or COP > 2,58	Text adjustable: -25 / +35
DHW	HP+ Boiler	Boiler	Only heating	HP+ Boiler	Boiler	HP+ Boiler

6 Reference cases

In the paragraph dedicated to the French housing stock characteristics, we identified two typical houses that can be a target for hybrids wide development.

6.1 Old oil-heated individual house

About 3 million individual houses are heated with an oil boiler in France. These houses have often been built before 1975, date of the first French thermal regulation that imposed for the first time a minimum level of insulation. They are in rural areas and are not connected to the gas grid.
For these houses, the replacement of old oil boilers by oil hybrid heat pumps is the most immediate and best way to reduce the energy consumption and the CO_2 emissions.
The typical old oil-heated individual house :

- Rural area
- Bad insulation
- Heated surface of 130 m^2 (110 to 150 m^2)
- Energy demand for heating and domestic hot water of about 20000 to 25000 kWh/yr

The hybrid product well adapted for this type of house (cf table in 3.3 paragraph) :

- Oil hybrid heat pump
- Heat pump power of 6-10 kW
- Boiler power of 23 kW
- Heat pump control based on CO_2 emissions or energy bill
- Domestic Hot Water produced by the heat pump and the boiler

The main obstacles for a wide development :

- The lack of knowledge of installers : it is easier for them to replace an old boiler by a new one
- The lack of awareness by the clients who don't know this type of products
- The capital cost of hybrid heat pumps, much higher than oil boilers one
- The oil price, which is very low for several months, doesn't encourage clients to reduce drastically their consumption

Despite these obstacles, the potential for the hybrids development in oil-heated houses is quite interesting. It can be accelerated by a sustainable increase of oil price and/or an evolution of the thermal regulation for existing buildings in the next future.

6.2 Existing gas-heated individual house

More than 5 million individual houses are heated with a gas boiler. These houses had been built in all periods since 1949 but an interesting share of them had been built between 1975 and 1989.
These houses are in suburbs of big cities or inside small or medium ones. They are smaller but better insulated than oil-heated houses. In these houses, the replacement of old gas boilers can represent a good opportunity to develop a market for hybrid heat pumps.
More precisely, we can define a reference case :

- Suburb area
- Insulated according to the 1982 thermal regulation
- Heated surface of 100 m^2 (90 to 110 m^2)
- Energy demand for heating and domestic hot water from 13000 to 17000 kWh/yr

The best-adapted hybrid product for this type of house (cf 3.3 paragraph) :

- Gas hybrid heat pump
- Heat pump power of 6 kW
- Boiler power of 20 kW
- Heat pump control based on CO_2 emissions or energy bill
- Domestic Hot Water produced by the heat pump and the boiler

The main obstacles for a wide development of hybrids in this market sector are globally the same as for oil-heated houses. In particular, the fuel price, which is regulated, more stable and lower in the case of gas, can reduce the cost efficiency of hybrids for this market sector.

6.3 New built individual house

At this time, the French market of hybrid heat pumps is mainly supported by the new built individual houses.

The main reason for that is the impact of the RT2012 thermal regulation. As said previously, this regulation imposes a (very few) part of renewables in the energy consumed in each new built house. Consequently, manufacturers and installers have created some products or combinations of products specifically designed to comply with this regulation, in a theoritical and minimum way, without any consideration for global energy efficiency.

The typical new built house :

- Climatic area H1 (coldest one in France)
- Well insulated
- Heated surface of about 100 m2
- Energy demand for heating and domestic hot water of 4000-5000 kWh/yr

The available product dedicated to this market sector is the following :

- Gas hybrid heat pump
- Heat pump power of 2-3 kW
- Gas boiler power of 24 kW
- Heat pump control based on primary energy criteria
- Domestic hot water produced by the boiler

A suitable product could be :

- Gas hybrid heat pump
- Heat pump power of 4-5 kW
- Gas boiler power of 10-13 kW
- Heat pump control based on CO2 emissions and/or energy bill
- Domestic hot water produced by heat pump in priority with the boiler in back-up

The main obstacles for the development of hybrids in this market sector are quite different from the previous reference cases. In particular, the capital cost of an hybrid heat pump doesn't represent a problem compared to other systems. The lack of awareness of clients can be a barrier but for a new built house, clients often seek advices to professional channel. Yet, it has been more trained and developped for this market by the French actors of the gas sector.

A References

[1] Ministère de l'Ecologie, du Développement Durable et de l'Energie, DGEC, Direction Générale de l'Energie et du Climat, **www.developpement-durable.gouv.fr**

[2] Loi POPE, Loi de Programmation fixant les Orientations de la Politique Energétique, 13 juillet 2005, **www.legifrance.gouv.fr**

[3] European Directive 2009/28/CE, 23 April 2009

[4] Plan d'action national en faveur des énergies renouvelables, période 2009-2020, août 2010, **www.developpement-durable.gouv.fr**

[5] Loi Grenelle 1, Loi de programmation relative à la mise en œuvre du Grenelle de l'environnement, 3 août 2009, **www.legifrance.gouv.fr**

[6] Loi Grenelle 2, Loi portant engagement national pour l'environnement, 12 juillet 2010, **www.legifrance.gouv.fr**

[7] PPI, Programmation Pluriannuelle des Investissements, Période 2009-2020, juin 2009

[8] ERDF, Electricité Réseau Distribution France, **www.erdf.fr**

[9] GRTgaz, **www.grtgaz.com**

[10] GrDF, **www.grdf.fr**

[11] Loi NOME, Nouvelle Organisation du Marché de l'Electricité, 7 décembre 2010, **www.legifrance.gouv.fr**

[12] CEREN, Secteur résidentiel – Bilan avancé des consommations d'énergie de 2015, février 2016

[13] RTE, Bilan électrique 2015, 2016

[14] Obsev'ER, Etude du marché des PAC 2014, 2015

[15] Commissariat Général du Développement Durable, Chiffres clés de l'énergie 2015, février 2016

[16] UNICLIMA, Bilan 2015 et perspectives 2016 du génie climatique, février 2016

[17] EHPA, European Heat Pump Market and Statistics – Report 2015, november 2015