UNIVERSITÀ DEGLI STUDI DI PADOVA

UNIVERSITA' DEGLI STUDI DI PADOVA

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Study of tendencies for cooling application in single family houses

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Alla mia famiglia, che ha sempre creduto in me.

A Silvia, che ha compreso le mie scelte.

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A tutti gli altri che non ho menzionato ma che hanno contribuito al mio percorso.

Abstract

Air conditioning of buildings has been in the past decades a growing sector and it has, in all the major markets (the American, the Chinese, and the Japanese) except Europe, the biggest share in the HVAC industry, in value terms.

Europe represents the second biggest HVAC market, and air conditioning is considered to be a sector with a potential still unexpressed, especially in the residential branch.

The Company Uponor GmbH is interested to understand how its products could be developed to be more competitive in the market in the next decades and how competitors are approaching this topic.

The study was supported with several reports, books and articles, but also with interviews to experts within the company and also University Professors as Prof. Bjarne W. Olesen and Professor Jarek Kurnitski.

There were considered mainly two different trends: a technological trend and a market trend, which they have led to an understanding of the technological development of the various cooling systems and of future market perspectives.

The analysis could be useful to comprehend where and how cooling systems will have more impact.

Contents

1. INTRODUCTION

US, China, Japan are the largest air conditioning markets in the world, and they have seen growing hugely the penetration of air conditioning during the past decades.

Europe remains to these days a market with a potential still unexpressed. The penetration of air conditioning indeed is definitely lower than the other Global markets, especially in the residential sector for whom in some European countries the penetration is practically zero.

The company Uponor GmbH is present on the air condition market as a producer of radiant systems, the purpose of this thesis is aimed to know if its products are under- or over-engineered or are still state of the art and if its systems could satisfy in the near future consumers' requests.

The thesis also have the purpose to study the technologies that until now have driven air conditioning in buildings in Europe, in order to try to predict how cooling systems could evolve in the next future and what impact they will have in the in the various European markets.

More in detail, the analysis starts from the study of the most relevant cooling systems in the residential sector, during the past decades, a research on what has been their evolution and which criteria have driven their development. Furthermore, it is interesting to observe the evolution of the market and the trend of the cooling demand in order to identify which external factors have influenced the evolution of both for the purpose of predict possible developments.

The tendencies that have been identified are of two types: a technological tendency and a market tendency. Both are linked to each other. It is interesting to analyze them separately and then coming to conclusions that concern both.

They were consulted specialized books and articles, company brochures and technical reports on the various air conditioning, heat pumps, and construction markets. All the research was supported and guided by a series of interviews to experts within the company Uponor GmbH with which have been analyzed the mainly topics regarding radiant technology and other experts outside the company which have supported the work with interesting ideas and clarifications regarding the study of the tendencies.

The thesis is structured in two parts: in the first one are described and classified all the various cooling systems and highlighted the strengths and the weaknesses. And a second part in which it is addressed an analysis of the different markets of selected European countries that follows an introduction where is defined the trend of the cooling demand in Europe in the next decades. Not all European countries were considered, the Key 6 European countries (Italy, Germany, France, Spain, Greece and UK) plus Turkey and Russia can represent really well the situation of the whole European market. Furthermore for an understanding of the trends in the Nordic countries were analyzed also the Finnish, the Swedish, the Norwegian and the Danish markets.

At the end of the most interesting paragraphs are reported final considerations which highlight the most important aspects of the various arguments. The considerations are intended to describe precisely the trends of cooling applications.

2. TYPOLOGIES OF AIR CONDITIONING SYSTEMS

2.1 *INTRODUCTION*

In the residential cooling application market is possible to find several types of systems. The chosen classification is the one proposed by the standard EN 15243:2007 which differentiates various air conditioning systems due to the type of cold production unit and cooling distribution system.
This classification has a weak point, in fact in the residential sector several systems that are described below are not very common. The choice that I have made is due to the fact that all the typologies of cooling application that nowadays are not often used, maybe in the future could have interesting applications in single-family houses. Especially those applications that have room for improvement. Furthermore the description of different systems allows a deeper comprehension of a technology perspective, for instance a system that nowadays is used almost for non-residential applications, with some modifications could be an interesting solution also for the residential one.
The different systems are evaluated considering the same criteria for each of them:

- Efficiency
- Dimensions
- Installation procedure
- Main components
- Terminal unit or complete system
- Product and installation costs
- Working costs
- Technological room for improvement
- Comfort conditions
- Control over multiple parameters

Each category of air conditioning system is more or less suitable in different climate conditions or in different building typologies. Each system diversifies from each other depending also on the installation procedure, in existing buildings, in new buildings or in installations as replacements in existing buildings.
Each technology has stronger and weaker points compared to the others. This study has the target to understand which the potentials and the limits are and where the technologies could be further developed, considering external sways that can influence future progression.

The standard Ventilation for buildings dictate a differentiation of the different technologies in three categories, “all-air systems”, “water-based systems” and “packaged air conditioning units”.
In following chapters are evaluated other components as heat pumps, chillers and dehumidifies, necessary for the operation of the systems.

2.2 ALL-AIR SYSTEMS

The systems are composed of:

- A refrigeration plant: a water coil with a chilled water plant or in alternative a refrigerant to air coil and the associated air condensing unit. An integrated refrigeration system instead of a water based system is a space and cost gain.
- A heating plant (if the system is also aimed at heating): a water coil with a boiler plant (electric or fuel based) or a direct expansion coil with a reversible air conditioning condensing unit.
- An Air Handling Unit (AHU) where the air, after a filtering treatment, is heated or cooled in its specific section, and humidified.
- A ventilator that allows the circulation of the air inside the ducts.
- Ducts for the air distribution.
- Terminal elements that distribute the primary air in the various rooms.

These systems treat the air centrally in an Air Handling Unit (AHU) and distribute it amongst the rooms through the ducts and the ventilator permits the circulation of the air.
The AHU for cooling applications can present simplified schemes, in spite of the more general configuration, depending on the purpose. A heating/cooling battery and an adiabatic humidifier for heating and cooling applications or a unique cooling battery for the only cooling application.
The cooling battery is usually powered by a chiller, a refrigerating machine that removes heat from a liquid via a vapor compression or absorption refrigeration cycle, the liquid can be used to cool air through a heat exchanger. The liquid that flows inside the cooling battery can be a refrigerant fluid, and in that case the cool refrigerant is supplied with an air conditioning condensing unit.
The installation of the system has to be done by an expert and it is quite onerous from an economic point of view but also from a working time point of view.
Considering the heating/cooling configuration, the battery can be powered by a reversible refrigerant working fluid machine. Hot water can be supplied by a reversible chiller or any other type of boiler.
The working environment conditions have to be guaranteed through the air inlet at Temperature, Humidity and Flow desired.
The system can be regulated in two ways:

- Controlling the temperature, keeping the air volume flow constant. Called constant volume systems.
- Varying the flow. Called VAV (Variable Air Volume).

Both systems, constant volume and VAV, can be divided in single duct and double duct.
The chosen classification divides different cooling systems first in single and double duct, in addition considers whether the air flow rate is constant or not (constant or variable volume).
There is a third considered case, the multi-zone system, it is similar to dual duct system, however the air is treated centrally and distributed to each room through ducts that carry the two mixed flows.

2.2.1 Single duct systems

Constant volume

a. *Single duct without reheat system:* it is the simplest system. In this type of systems the air flow has the same thermal conditions, even though the flow can be different in the various rooms. The AHU carries the air at humidity and temperature conditions in every room. All the entry points, in the psychometric diagram, has to be in the same straight ambient line. If there are rooms with different thermal load it is not possible to vary the air conditions per room.

b. *Single duct with multi-zone reheat system:* the regulation is realized by way of batteries placed in every single room and controlled usually by a thermostat placed inside the room. However, the various rooms can have different requirements, so often it is not possible to obtain the desired comfort conditions (Temperature and Humidity), only Temperature and not the Humidity and vice versa. When the regulation is done on the temperature the inlet conditions are varied with the changes of the local loads so as the set-point temperature is guaranteed and the humidity will shift on the straight ambient line.

Variable volume

a. Volume air flow control: these systems are able to vary the air flow keeping the set-point temperature constant, facing a variable sensible load different from the set point one.
Variable geometry terminal elements are essential to change the air flow, they are controlled by a servo-motor in contact with a thermostat.
For a correct operation of the system the pressure downstream the ventilator has to be constant, it is important while the variation of the flow in a single room can influence the variation in another room.
The regulation is done only on the temperature inside the room and it can be a problem for humidity levels.
Furthermore, the air flow has a limit due to acoustic levels, the air can be very noisy. For this reason the air flow can be limited until 60% of the nominal one.

2.2.2 Double duct systems

Two different ducts, one for cold air and the other for hot air, are used for the distribution of the air. This is the perfect solution in cases where the dwelling is composed by different rooms which have various thermal requirements.
The input air in every single room is a mix of the two flows, the mix is done in a mixing box placed close to the room.
The air flow is controlled in both ducts through shutters, controlled by a thermostat which regulates the mix.

2.2.3 Multi-zone system

It is a compromise between single duct and double duct systems. These systems can be a good solution for very big buildings where there are different zones with different thermal requirements. The air is treated centrally at the same conditions or Relative Humidity, but at different temperatures depending on the rooms. The new air is combined with the recycled one. First, the new air passes through a cooling battery, at T=12-13°C and x=1 (close to saturation) and flows into a so called "cool plenum". The old air, on the other hand, goes through a heating battery and flows into a so called "warm plenum".

2.2.4 Evaporative cooling

In addition to all-air systems illustrated above, evaporative cooling is a process that can be combined with all-air systems, and even the main process alone can be a solution.
The evaporation of water in air can be very effective, especially in hot and dry climates, the water from the outside can be cooled and directly inserted in the room. On the other hand, the potential for evaporative cooling, applied as a cooling system, decreases when the humidity levels of the climate tend to saturation.

- Direct evaporative cooling: outdoor air flow passes through an adiabatic saturator in which drops of water evaporates into the air absorbing heat from the air.

- Indirect evaporative cooling: the primary air flow passes through a heat exchanger and a secondary air stream cooled by water reduces the primary air temperature.

During the heating season, if the exhaust air is used as secondary air stream, the indirect system can be used as preheater.

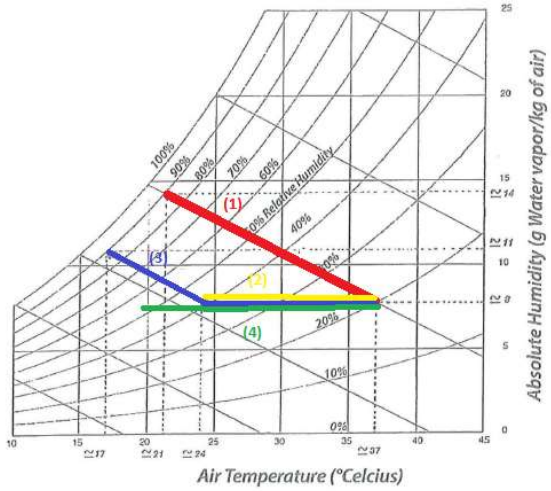


Figure 2.1: Pathways (1), (2), (3), (4) on a simplified psychometric chart

- Indirect/direct evaporative cooling: the primary air is first cooled with an indirect evaporative cooling process, and then cooled directly with water drops.

- Indirect/indirect: In the first stage, the primary air is cooled with an indirect evaporative cooling. In the second stage, cooled air passes through the wet side of a coil and additional sensible heat is removed from the primary air stream.

It is a very cheap solution, and it is very effective especially in hot and dry climates, it is also an interesting solution for the residential sector both single and multi-family houses.
Evaporative cooling requires a good quality of water while it can led to health problems (legionella).
It is also possible to integrate the system in an AHU. The direct expansion treatment can be used to supply pre-air treatment of fresh air in AHU.
Evaporative cooling can be in the future a very interesting cooling application, it has technologically speaking room for improvement. However, it is not a suitable technology for very humid climates, furthermore dimensions is not an unimportant problem as well as aesthetic of the system but still can play a very important role in dry climate markets.

2.2.5 Considerations

All-Air systems represent a very popular typology of system in North America where buildings are new and have usually big dimensions and the type of construction (light structure) allows the application of big ducts and simplifies eventual changes on the system.
It means that this is a solution hard to apply in renovations, the system has to be thought from the beginning as part of the dwelling.
The primary air treatment is a very positive point of this system, in fact the air is filtered and the distribution of it is very accurate, also it is possible to control the temperature and/or the humidity and the air is filtered.
All-Air systems are used not only for cooling application, but also for heating (manly for heating) and the possibility to use the system for the dual application is very common and in some cases there is also the possibility to produce domestic hot water.
It is possible to grasp that these systems are very complex, bulky (the air distribution ducts, all the components for the air treatment), expensive and hard to design (the balance and the calibration of the ducts). They are not very common in Europe for residential applications, however in North America are a very common solution in single-family houses. There are some interesting products on the market, as high efficiency heat recovery solutions, with production of sanitary hot water, heating and cooling applications (Compaq P-Nilan).
But also compact solutions as winter and summer ventilation.
The prices strongly depends on the installation procedure, on the length of the air distribution ducts and on the sources used for cooling and heating.
All-air systems are not a good solution for the only cooling application in the residential sector. The price of the system is quite high and investment costs could be bearable when the system is used for both heating and cooling applications.
The all-air technology is a very interesting solution in combination with a heat pump, in heating and cooling applications where the same system takes care of winter and summer operation, contributing also at the air

replacement and in some cases also domestic hot water. It can also be matched with renewable energy sources as for heating as for cooling, for example with a geothermal heat pump.

2.3 WATER BASED SYSTEMS

The systems are composed of:

- A Chilled water plant[1].
- A hot water plant (if the system is also aimed at heating).
- An Air Handling Unit (AHU), when it is needed. Sometimes the AHU is not present, instead of it there is a dehumidifier that modifies the humidity of the air inside the room or the air outside doing an air replacement. Also in some climatic areas (as Northern European countries), where is not needed, there is no AHU or a dehumidifier.
- Ducts for air distribution, where the AHU is present.
- Terminal units that can supply cooling and heating and when is needed additional functions as dehumidification and air treatment. Several types of terminal units are available (EN15243:2007): fan coil units, induction units, radiant cooling panels (floor, wall, and ceiling), passive and active chilled beams, embedded systems.

Water based systems can be classified in two different categories due to the dominant thermal exchange mechanism of the terminal elements:

2.3.1 Convection systems:

The terminal elements that use convection as dominant thermal exchange mechanism are fan coil units, induction units and chilled beams.

Fan-coil units systems:

FCUs are terminal elements which are able to release heat or subtract heat from the air through forced convection of the air (winter or summer mode).

Fan coil units appear usually as compact devices to install on the floor, ceiling or wall.

Usually, a fan coil unit is composed by a metallic or plastic structure where all the components are contained. One or two thermal batteries may be present, in several cases the cooling/heating battery is powered by chilled or heated water, in some other cases one battery is powered by chilled water, while for heating an electric resistance is used.

During summer operation the air, which crosses the chilled battery, deposits part of the water contained in it in a water container placed below the battery. This water has to be removed for health reasons.

The temperature of the water inside the cooling batteries is in the range 5-10 °C.

The cooling source can be a reversible heat pump but also a chiller.

The system can be classified in two versions with or without the primary air treatment and for each of it, we can identify two possible configurations, the 2 pipes or the 4 pipes.

[1] In some cases the chilled water plant and the hot water plant are the same reversible plant (Reversible Heat Pump)

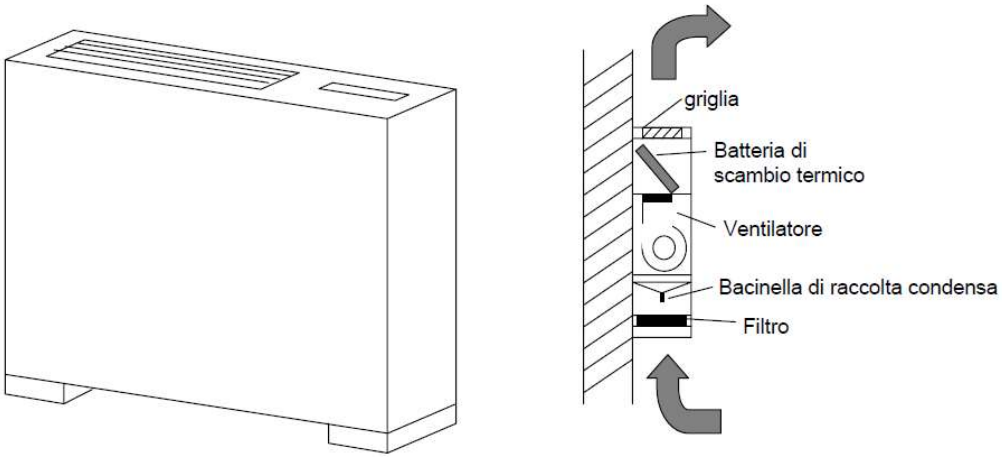


Figure 2.2: Fan coil unit – source "Impianti di climatizzazione", UNICH

a. *Primary air fan coil:* the system is divided in two separate sections: one where cooled water (in our case, but also heated water), which obtains the cooling effect from a cold source, is sent to fan coil units and the sensible load is controlled.
The relative humidity is not controlled, and this is what the second section of the system does, in fact an AHU, powered by a cold plant, through distribution ducts, controls the relative humidity (the latent load) and the quality of the air and sends it to the rooms. The air flow is constant and its velocity is low. The regulation can be done controlling the inside temperature and humidity conditions following the outside temperature.
The dehumidification handled by the cooling battery is inaccurate that's why it is better to give to the primary air the complete control of the humidity.

b. *Fan coil unit without primary air:* is the simpler and more economical solution of this system. The only fluid which is handled is the water that flows inside the fan coil unit. This is a limit for the simultaneous control of the temperature and the relative humidity of the room. In some cases the ventilation is entrusted to specific outlets close to the fan coil unit.
The most economical solution uses the natural infiltration of the external air.
There are some disadvantages as the noise of the fan coils but also the need of maintenance work due to the presence of an electric line, electro ventilator, one or two thermal batteries and other components.

Induction units systems:

An induction unit is composed by a thermal battery for heating and/or cooling loads, a plenum where the high pressure air flow is pushed from the central air conditioner and an air distribution system with which the primary air is distributed. A shutter regulates the air flow.
From a technical design point are very similar to fan coil units systems. In both cases the primary air is used to handle the latent loads (the complete control of the humidity), and to provide the correct supply of replacement air. The water circuit handles the sensible loads.

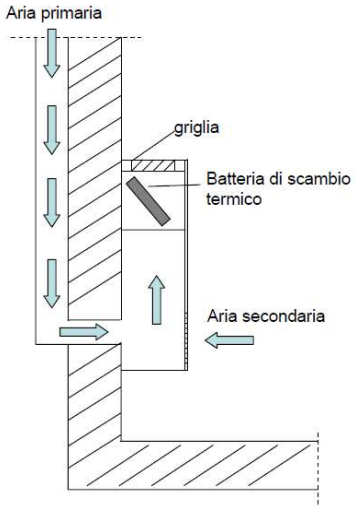


Figure 2.3: Induction unit – source "Impianti di climatizzazione", UNICH

The difference between these two systems is that in fan coil units the air is pushed inside the room by the ventilator. Induction units do not have a ventilator and the primary air coming out from the ducts creates a depression that recalls the air in the room (3-6 times the primary air) to pass through the chilled/heated battery.
Furthermore, compared with fan coil units with which the air is generally distributed through nozzles placed inside the rooms, with induction units, primary air has to be supplied to the final element through a duct that usually has to cross the room and arrive to the terminal element. The system is more bulky and sometimes it is needed a false ceiling with resulting higher installation costs. But the non-presence of the ventilator reduces maintenance costs.
It is a very similar terminal unit to fan coil unit, and the considerations done for fan coil units can be done also for induction units.

Two or four pipes systems:

For both fan coil units and induction units, the water distribution can occur in two possible configurations, the 2 pipes or the 4 pipes one.

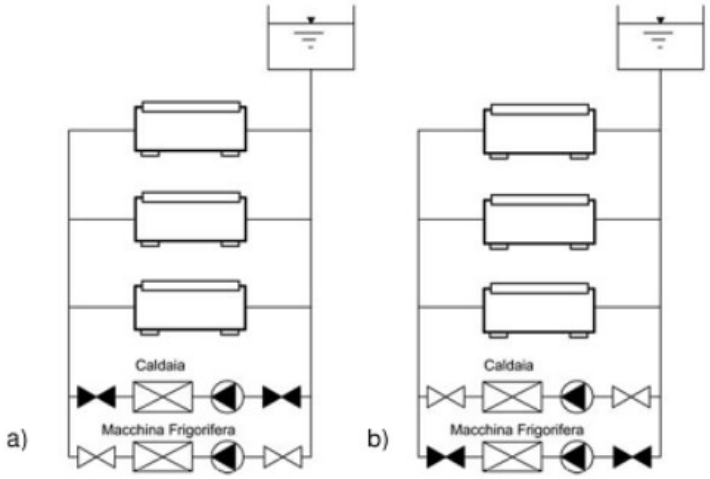


Figure 2.4: (a) 2 pipes cooled circuit configuration (b) 2 pipes heated circuit configuration – source Impianti di cliamatizzazione e condizionamento, C.Buratti

The 2 pipes configuration considers that a cooled or a heated fluid flows inside the water distribution system, depending on the room needs, represented in the figure below. In this configuration all the terminal elements are or all cooled or all heated, while it could be necessary the same time cooled and heated terminals. When the system changes from one to another seasonal operation, it is needed the so called "commutation" of the circuit. The 2 pipes is the most common configuration, it is used as for mono residential applications as for centralized applications.

To avoid the "commutation" of the circuit and allow the contemporary heating and cooling in different rooms the 4 pipes configuration is the solution.

The 4 pipes configuration permits, in every season, the feeding of cold or warm water in every room depending on the needs. It is possible to cool or heat different rooms in the same time. The user has the control of the regulation.

The "commutation" is not needed while, during intermediate seasons, the heating loads are handled by the fan coils.

This is obtained doubling the hydronic network so the two circuits are separate.

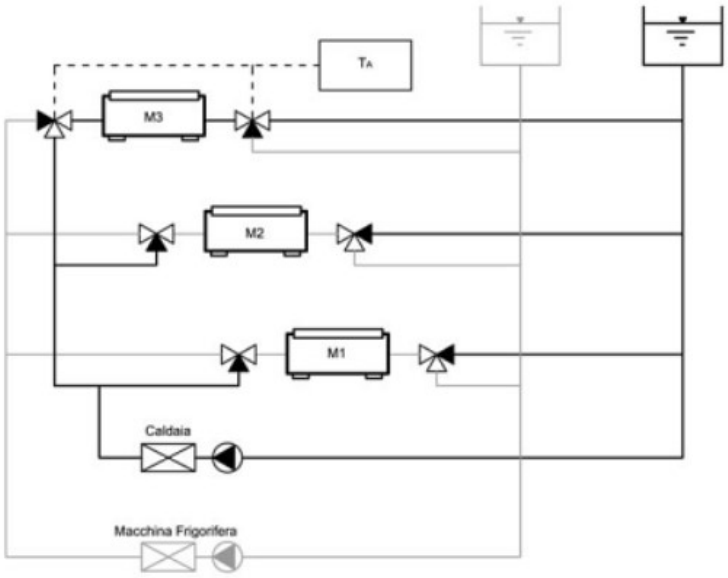


Figure 2.5: 4 pipes circuit configuration, M1 and M2 are fed by the cooling circuit, M3 by the heating one – source Impianti di cliamatizzazione e condizionamento, C.Buratti

Furthermore the terminal elements have two different batteries, one for hot water and one for cold water.

These systems are more expensive compared to the 2 pipes, and also the terminal elements are more complex.

This solution is less common in the residential sector.

Chilled beams systems:

A chilled beam system consists in a complex of elements that controls the microclimate in a room through the coupled thermal exchange mechanism of convection and radiation, except for terminal elements without radiant surfaces.

There are two different type of chilled beams: one, so called passive chilled beam, a fin-and-tube heat exchanger, where the chilled water passes through the pipes, warm air from the room passes toward the beam and the air around is cooled. The cooled air descend toward the floor.
Active chilled beam on the other hand, consists also in a fin-and-tube heat exchanger contained in a structure that is suspended from the ceiling or integrated with the ceiling. The main difference is that active chilled beams have a primary air circuit integrated. The primary air passes through nozzles, which induce air from the room to the beam. Active chilled beams have much more capacity than passive ones.
These systems are usually used for cooling applications but can also be used for heating ones.
The water distribution can be in the 2 pipes or the 4 pipes configuration. The temperature of the cooled temperature is relatively high, a good solution for keeping operative costs relatively low, and also a condition that favors the use of heat pumps.
Chilled beams are not really often adopted in residential applications, but it still is an interesting solution. There are several types of terminal elements from the false ceiling ones to the ones that have integrated lights on it.

2.3.2 Considerations

Fan coil unit systems have several applications, from the residential and light commercial sector to the industrial sector. The fan coil units without primary air system is generally adopted in the residential sector where natural replacement of the air is the most common solution.
The primary air fan coil solution is more expensive and more space is needed that's why it is the prevalent solution in the nonresidential sector.
These systems can satisfy heating and cooling loads and they are mainly chosen for the first reason.
The primary air flow is constant and it is distributed at low velocity.
The installation of the system is quite difficult in refurbishments where a specific water circuit is not present. However it is a good solution for replacement applications of radiators or old fan coil units.
The terminal elements during the last years went through several improvements, they are more integrated in the room, less visible and in the same time less noisy (one of the biggest problems) and also in heating and in summer operation FCUs are able to exploit lower and higher temperatures respectively. Latest products are able to provide heating also with low water temperatures and they can be used in combination with heat pumps (Air/Water). Cased models are the prevalent terminal elements sold on the market.
In general it is possible to say that fan coil units are present in the residential sector for the heating needs and the cooling configuration is an integration to the classic system.
However, the reversible fan coil system, according to JARN, in Germany in 2010, 60% of the total sales were heating and cooling models.
It is a technology that is quite stable from several point of views, in the last 15 years the technology improved to a better integration of the terminal elements inside the rooms, also the noise problem is nowadays solved. It is a good alternative to radiators and the possibility to provide also cooling with the same system is a great advantage.
FCUs can be matched also with absorption chillers, in countries where Natural Gas is the major thermal source (in Italy for instance) could be a good choice.
All the considerations done for FCUs are valid also for induction units. Price for a FC unit is about 400 – 600 €.

2.3.3 Radiant systems:

- *Introduction:*

Radiant system is one of the most common heating solution (especially in northern Europe) but it can be also used for cooling applications.
Interest is nowadays more and more addressed to radiant cooling applications, while radiant heating is already a very popular technology.
Radiant systems are composed by pipes placed behind a specific surface inside the room, installed in three possible locations: floor, ceiling or wall, even if the last one is the less common solution.
Warm or cold water circulates inside a closed water circuit, usually composed by plastic material pipes, which fills an extended radiant surface.
An insulating layer is inserted between the building structure and the pipes.
The manifold is designed for the water distribution, for a better control of the thermal emission.
A dehumidifier or a primary air system can also be present in cooling operation, in fact cooling radiant systems have the limit that their efficiency strongly depends on the dew point temperature of the air, when the cooled surface temperature decreases beneath the condensation temperature of the air, a condensed water layer can form on the surface. This fact entail a careful control on the relative humidity in the room and in specific climatic zones a dehumidifier or a primary air system is needed.
Radiant systems can supply only sensible load. Latent load has to be supplied by the air system when present.

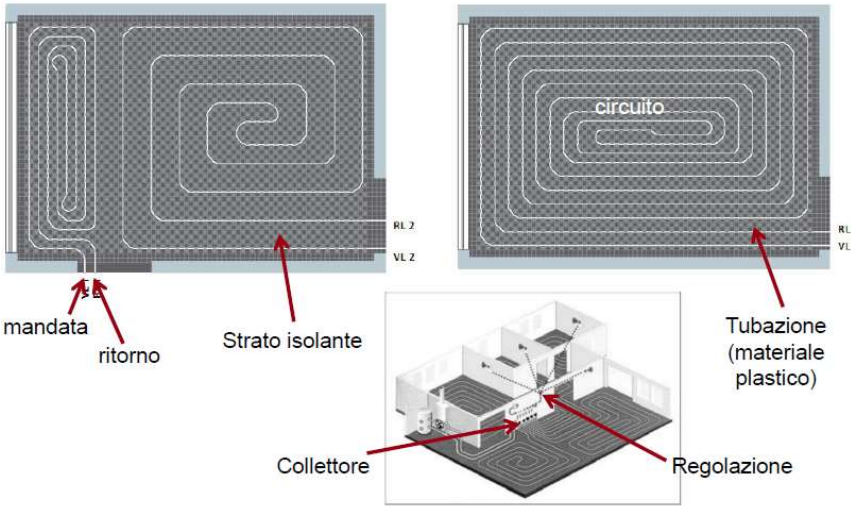


Figure 2.6: Radiant system components – source Q-RAD

- *Classification*

Radiant systems can be classified in three possible categories:

- Underfloor radiant system
- Ceiling radiant system
- Wall radiant system

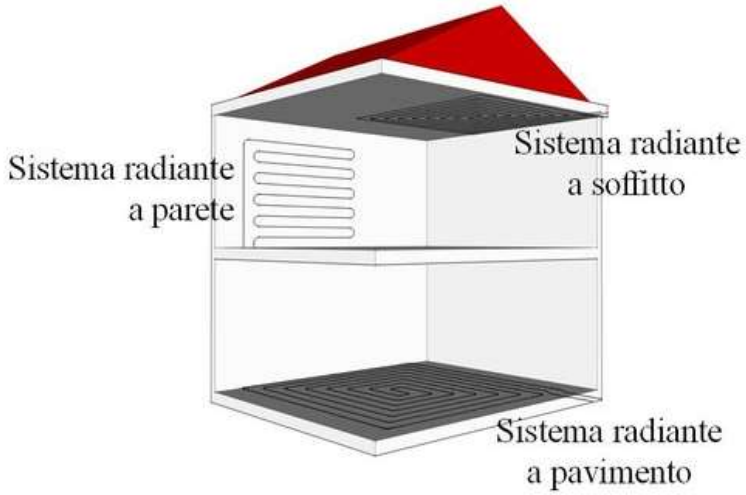


Figure 2.7: Different typologies of radiant systems – source Q-RAD

For each category, there are different types of configuration depending on the thermal needs, more specifically it is related to the concept of thermal inertia, the "velocity" with which the system follows room temperature's variations.
Two different typologies of radiant systems can be identified:

- High inertia systems: pipes drowned in ceilings or floors.
- Low inertia systems: prefabricated panels, mounted in false ceiling or walls. Or "low thickness" underfloor systems.

Compared to others cooling systems, very high inertia radiant systems (TABS) have the property of varying slowly the surface temperature in reaction to room temperature variations, as mentioned in the standard EN 11855-2012. Considering the same thermal energy demand of a building, this property permits to choose a relatively lower peak load power source compared to other cooling or heating systems for TABS.
However in the case of classic radiant underfloor, ceiling or wall systems the energy consumption matched with a chiller in cooling operation compared to a fan coil unit for instance is more or less the same.

Underfloor radiant systems:

This is the most common solution for heating operation and it is considered the best solution for this application, but nowadays is also a good application for cooling. It has ideal characteristics for a reversible use. Underfloor systems have better efficiency in winter operation due to the thermal exchange mechanism, this aspect will be analyzed in more detail below.
It is a good solution when the ratio between transparent surfaces and walls is low.
A traditional underfloor configuration is pipes drowned under the floor, with a typical thickness of 65 mm. However nowadays also "low thickness" radiant systems are very popular, while are easier and faster to install.
Traditional prices for an underfloor radiant system can be from 30 to 50 €/m^2.
The product development is moving towards easier and faster to install products and to a standardization of products where the installer has less work to do.

(a) (b)

Figure 2.8: (a) High inertia underfloor radiant system, high thickness. (b) Low inertia underfloor radiant system, low thickness – source UPONOR

Ceiling radiant systems:

A possible configuration can be, as described for underfloor systems, pipes drowned into the ceiling. However, ceiling systems find a better application in low inertia configuration. They have very good performances in summer operation, indeed the property of having high reactivity to temperature room variation is fundamental. They can also be installed in renovations.
It is also a good choice in dwellings with high transparent surfaces and walls ratio.
Typical prices for ceiling radiant systems are more or less double of the prices for underfloor radiant systems, from 60 to 150 €/m^2, the price strongly depends on the installation procedure.

Figure 2.9: Low inertia ceiling radiant system – source Q-RAD

Ceiling systems is the best configuration for radiant cooling applications, the product's development is moving towards, as for underfloor radiant systems, easier and faster to install solutions and to standardized products but also to panels aesthetically speaking more integrated in the rooms. Especially in residential applications where the presence of a ceiling radiant gives the feeling of being inside an office.

Wall radiant systems:

As previously mentioned, this is the less common configuration. However, whenever neither the floor nor the ceiling can be used, wall radiant systems can be the perfect solution.

There are several configuration, and the inertia of the system, as for underfloor and ceiling applications, depends on the cladding. The same considerations done for underfloor and ceiling radiant systems can be done for wall systems.

- *Technical aspects and system regulation*

The radiant exchange mechanism grow exponentially even with small water temperature increases, that's why radiant systems can work with relatively low temperatures during winter operation and with high temperatures during summer operation.
Several important researches have revealed that radiative thermal exchange, of low temperature heating systems and high temperature cooling systems, can be considered a constant value of 5,5 W/m^2K, when the surface is a gray body. The convective thermal exchange depends on many parameters: the temperature of radiant surface, the air temperature and its velocity. It is easy to understand that the position from which the thermal power is supplied is fundamental. Underfloor systems used for cooling cannot take advantage of convection as much as radiant ceiling cooling systems do and vice versa for heating application.
For fixed operating conditions, cooling power supplied by an underfloor system is approximately half of the power supplied for heating. Opposite values describe the operation of ceiling systems.
More generally, underfloor radiant systems are more suitable for heating applications while ceiling systems are for cooling.
In cooling operation, the cooled water circulates at average values of 16-17°C depending on the dew point temperature and in heating operation, in the same way, the average temperature is around 35°C, over or beneath classic values of other traditional heating or cooling systems.
Compressor chillers supply the water circuit with cooled water, while for combined cooling and heating radiant systems, a reversible heat pump is usually used or in other cases a heat generator is in addition to the chiller.
It is possible to underline the fact that radiant systems can be easily matched with alternative sources as solar or geothermal ones.
Cooling radiant panels are, technologically speaking, equal to heating ones. However, they are more difficult to design since the analysis has to be done in dynamic conditions and moreover radiant panels strongly depends on solar gains and internal gains.

The regulation of the system can follow three principles:

- Fixed point: it is the easier regulation, a fixed temperature is guaranteed as operative temperature of the system. The user can change settings manually. The thermostat compares the set temperature with the present one and it turns on or off the actuator.

- Climatic thermoregulation: it is a more efficient regulation, two sensors are connected to a centralized control, one sensor measures the outdoor temperature and the second one measures the operative flow temperature. The centralized control elaborates the outdoor sensor signal and acts on a mixing valve.
- Smart climatic thermoregulation: in this case, four sensors are connected to a centralized control, one measures the indoor room temperature, one the outdoor temperature, the third the operative flow temperature and the latter

the humidity. The centralized control acts on the mixing valve managing the water flow temperature and on the dehumidifier. In presence of an AHU, the regulation is more complicated but still is becoming a solution increasingly used.
A room control can be also done, handling room by room the percentage of water flux.

2.3.4 Considerations

Ceiling radiant cooling technology (the ceiling configuration) is very often adopted in the tertiary sector while in the residential one counts a few applications. This is due to the fact that a radiant system for the only cooling application in the residential sector is quite expensive compared to other technologies (as split systems), the installation procedure is complicated and the awareness of this technology is not widespread.
Radiant systems need an outdoor unit as cooling source, a compressor chiller or a heat pump and usually, even for small power units it is very expensive. The price for chillers and heat pumps are relatively higher for lower-powered units and it becomes relatively lower for bigger-power units. This makes radiant technology more suitable for bigger space applications as for example commercial and tertiary sector, less for the residential.
The development of radiant systems is moving towards to less expensive and easier installation solutions and at the same time a standardization of products is required to be more competitive and to reduce design costs.
In addition to this, the energy source is as important as the terminal element, because the only radiant system cannot supply cooling and or heating and for this reason it is appropriate to think about a complete product. For instance, commercially speaking a chiller or a heat pump and a radiant system sold as a unique solution.
Furthermore in several climatic zones it must be provided a dehumidification system or an AHU to take care of latent load and/or of replacement of the air.
Radiant cooling has several advantages, compared to other cooling systems, the air flow is reduced to the only ventilation and air changes, and comfort levels reached are very high.
Underfloor radiant systems are the best solution for heating applications and their presence in European dwellings has been increasing since several years. This aspect is very important while future installations can be thought as combined cooling and heating solution with a consequent higher distribution and awareness of this technology. However, they have a limit on the maximum power which can be supplied for cooling in the case of underfloor radiant cooling and for cooling in the case of radiant ceiling.
Considering the unique cooling function, radiant systems (ceiling) cannot compete with split systems in the residential sector, they are too expensive and their cost is not depending only on their cost but also on the cost of the chiller, which it has a cost proportionally lower as the power of the chiller increases. Furthermore, the installation procedure is quite hard and aesthetically speaking, ceiling radiant are not considered suitable for a residential ambient.

2.4 RESIDENTIAL AIR CONDITIONING UNITS

The standard EN15243:2007 uses the word “PACKAGE” for this category, while it is commonly used to distinguish split units from package units (those whose components are on a single block).
Residential, in this case, means units which do not require other components (as terminal elements, or sources) to accomplish their duty.

All the systems may be in heat pump version and they may therefore have both summer and winter applications, so they can also provide heating. Heating can be provided either by an electric resistance, or by reversing the cycle, and eventually by using both (the electric resistance as a complementary component). They can also be for the only cooling application.
The different types of residential air conditioners are classified following the commercial categorization, more in detail they are divided in sub categories due to the place where the air is threated (centrally or room by room).

2.4.1 Room Air Conditioners (RACs)

They are a combination of different components of a refrigeration system electrically driven which typically supplies chilled air to a single room or multiple rooms of a building, but they can also be used in winter operation when the unit is in heat pump configuration. The name Room Air Conditioners (RAC) characterizes the fact that the threated air is the one inside the room, there is not a primary air contribution.
They are classified in two categories: fixed and movable. They all have behind the same refrigeration cycle.
A compressor, a condenser, an expansion valve, an evaporator and the refrigerant fluid are the main components of the system, which can all be in the same structure or split.

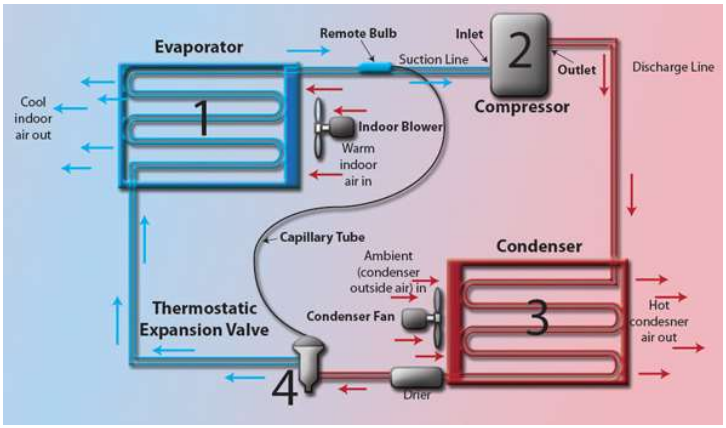


Figure 2.10: Refrigeration cycle

Room air conditioners is the more widespread solution overall residential air conditioning markets in term of sold units.
They are able to remove sensible and latent load from the air, reducing the air temperature and taking care also of the humidity. The removed water is collected in a specific tank and it can be taken away manually or automatically.
Normally the air is treated directly inside the room, however it is possible to supply the room with a primary air flux with the assistance of an additional renewal air system.

Fixed

- *Split-packaged units (single-splits or ductless splits)*

The term split is used to describe the installation of the system, one unit is placed outside the building where the compressor and the condenser are, while the thermal expansion valve and the evaporator represent the indoor unit.

This description illustrates the cooling operation of the system, however the system can operate also in heat pump configuration.

Figure 2.11: Single split unit - source DAIKIN

The two units are connected by a pipe which carries the refrigerant fluid and transfers the heat out of the room from the evaporator to the condenser.

Split units are very easy to install, flexible for cooling and heating and they are very responsive. They are also an economic solution, and the dimensions are contained.

Every system has totally independent control and the user can set the desired temperature. The sensor, following the temperature variations in the room, would provide cooling or heating.

The pipe line is quite small, it is easily hideaway.

Every system needs an outdoor unit, it is an impact on outdoor building aesthetics.

If more than one single-split unit is expected in a dwelling, more than one outdoor unit per house entail its presence with consequently bigger impact on building's appearance.

The air flux is limited to restricted areas inside the room which can lead to possible cold spots and also to annoying cold air streams.

There are several types of terminal elements: from the most popular solution, the wall mounted type, to the floor standing type or the ceiling mounted cassette, and others, as shown in the following figure.

Figure 2.12: Different typologies of terminal elements

Single-split systems are the most widespread cooling technology in all over the world.

The refrigerant mostly used is R410a.

The price for single-split varies from country to country among Europe. Average prices for units of power under 3.5 kW are in the range of 400 - 2000 € depending on the efficiency of the system and the design of the terminal unit. Installation costs varies depending on the power of the split system and on the distance between the external

unit and the internal one, average prices are in the range of 200 - 500 € for units not far from the external unit more than 6 meters.
For a total cost from 600 – 2500€ for a single-split system.

- *Multi-split packaged units*

Non-ducted multi-split units:

Multi-split units are the evolution of single-split units, they operate on the same principles. To a single outdoor unit (condenser) are connected multiple indoor units (evaporators) up to nine units (four units is the average value). Every indoor unit is connected to the outside unit individually, and the external part of the system takes care of each evaporator. Each indoor unit has its own refrigerant pipe line.

Figure 2.13: Multi-split unit with different examples of terminal elements – source LG

These systems are the perfect solution for applications where the installation of air ducts is difficult to apply or too expensive, but it can also be a very interesting alternative to multiple single-split units all installed in the same dwelling (it is convenient when the number of single-splits is over three), resulting in a reduction on the number of external units.
Internal units are not esthetically appealing, inside a dwelling can have a bad impact. However in recent years several single and multi-split's producers have been trying to make the terminal elements more suitable for internal design.
The pipe grid which carries the refrigerant fluid requires small dimensions and each evaporator has its own refrigerant pipe connection. However, the maximum length of refrigerant pipes is limited, in particular all split systems have a maximum vertical and total refrigerant pipe-grid length. This is a very important disadvantage for these systems compared to all-air or hydronic systems where the pump is dimensioned to suit the system needs. The maximum length is determined by the power of the compressor.
Multi-splits can fulfill multiple rooms but with similar heat loads, they are not suitable for dwellings that require in the same time heating and cooling, the final elements can only satisfy one requirement.

First generation of multi-splits utilized single-speed compressors, the individual temperature control of the indoor units was not possible, the regulation was done only with a single thermostat controller used for the whole system, and all indoor units would function as a unique unit.
It was not a good solution for dwellings with different heat gains, the control would sense only a single temperature sensor for all rooms.
In new generation of multi-split systems every indoor unit has its own individual temperature controller, thus in every room can be maintained a single temperature. However, there is a limitation, even though different temperatures can be maintained in different rooms, it is not possible to provide heating in one room if another room is already asking for cooling.
The different terminals are fed by the same compressor which cannot function in heating and cooling mode simultaneously.
The transition from the first to the second generation of split units was possible due to the inverter driven compressor application.
Modern mono and multi-split systems are by now all inverter driven.
The refrigerant mostly used is R410a.
The price for a multi-split system depends on the number of unit annexed to the system. Considering an average number of four units for a residential dwelling and a power range from 7 to 9 kW, average prices are from 1500 – 3000 € for the external unit depending on the efficiency and the quality of the system, plus an average price of 400 - 600 € for each internal unit depending on the design of the terminal unit.
Installation costs varies depending on the power of the split system and on the distance between the external and the internal unit and the price is on the range from 1000 – 1300 €.
For a total cost in the range between 4100 – 6700 € for a multi-split system with 4 internal units.

Inverter driven compressors

The inverter is used to control the speed of the compressor (scroll or reciprocating models) and so regulate the room temperature, used with sophisticated refrigerant control and electronics pushed this technology to a more complete system able to monitor and modify different room temperatures.
The inverter compressor is programmed to run at the optimum speed which is controlled by input frequency that varies according to the internal load, therefor this entail a reduction on energy consumption.
In first generation of split-systems, the compressor stops when the set temperature is reached and starts again when the room temperature is under or over a set temperature difference. This start and stop cycles entail considerable room air temperature variations and high energy consumption.
Moreover, during start up, the compressor does not recall high current like conventional air conditioning systems. This is an additional aspect of energy savings.
Inverter driven compressors are now also used in single-split systems.
Inverter split models are nowadays the most common solutions and in term of sales they represent more than 70 % of the total market share.

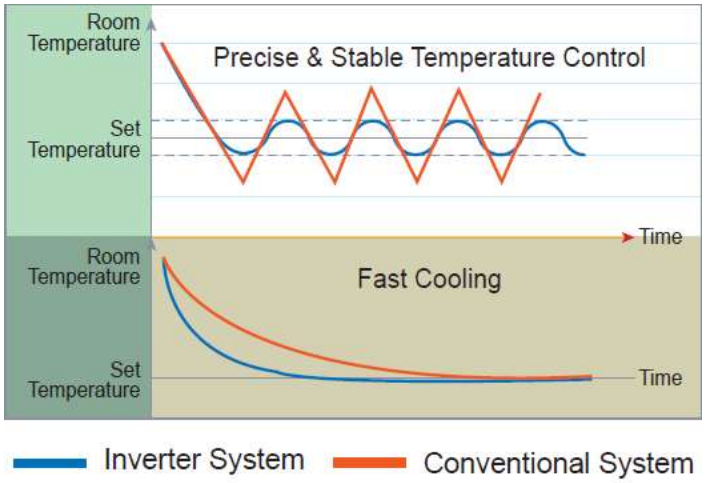


Figure 2.14: Inverter driven system vs conventional one - source ACSON

The penetration of inverters in the air conditioning market saw an increasing penetration, especially in the last five years. In China for example, inverter model air conditioners have grown from 7% to 51% until 2012 and still growing. Nowadays almost all single and multi-split systems available on the market are all inverter driven.

- *VRF*

These systems are very similar to multi-splits. Terminal elements are all connected to one single outdoor unit, however the main difference is that in multi-split systems there is always the same amount of refrigerant in each pipe connection between evaporators and condenser, whereas VRF systems continually vary the flow of refrigerant which feed each indoor unit.

The main advantage of VRF systems is the possibility of terminal elements to provide in different rooms simultaneously cooling and heating requirements. Moreover, the removed heat from the cooled room can be used to provide heating in another room.

The user can set different room temperatures in each room and the system automatically tunes the refrigerant flow to each indoor unit.

VRF systems are able to modulate the rooms' temperatures very quickly and also stabilize the temperature under a limited range. The system is also capable of a humidity control.

As multi-splits, indoor units can be mounted in different places and can also be of different typologies for the same system.

Dimensions, compared to other air conditioning systems, are contained, starting from the outdoor unit which requires limited space, to the ducts that have to carry only the refrigerant and are also lightweight.

Compared to multi-split systems, VRFs have lower installation costs while copper is less used in ducts.

It is also possible to match with VRFs a separate air ventilation system that provides filtered primary air to the dwelling.

VRF systems have higher energy efficiency values compared to multi-split units and are also able to control with a single outdoor unit more than forty-eight internal ones.

The control is realized using a pulse modulating valve (PMV) that regulates the refrigerant flow. The section variation of the valve is determined by a central electronic control that receives input from temperature sensors placed in each room. The terminal elements are connected to the outdoor unit (the compressor) and responds to the indoor units' demand varying its speed and follow the variations of the internal loads.
The compressor is usually an inverter-driven scroll compressor changing its speed in function of cooling and/or heating load variations.

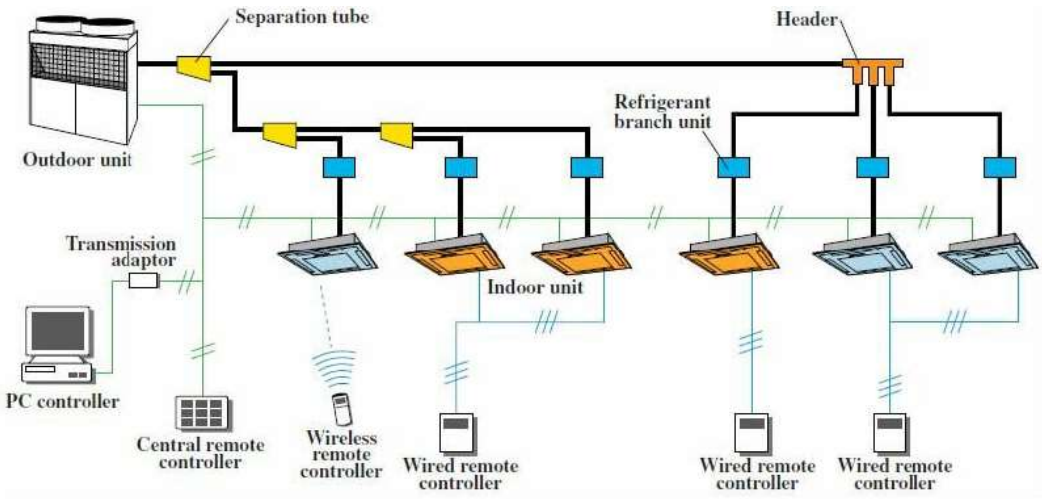


Figure 2.15: VRF system - source PRIMUS

The refrigerant pipe grid has limitation on the maximum length, as multi-split one has. The main limitation is the restricted distance between the condenser and the evaporator, and also between two indoor units.
This limitation is connected to the compressor, as for all split systems, and this is the biggest limitation comparing VRFs to other air conditioning systems as hydronic driven ones or all-air systems.
Installation costs of VRF systems are very variable, depending on the project design. It means that these systems are solutions that expect a design behind, they are not as single-split or multi-split systems, simple and easy to install solutions.
VRF systems are widely adopted in the tertiary and in the commercial sectors as Hotels, schools, office buildings and so on, not widespread in the residential one.
However this is the latest evolution for multi-split systems and it is a really interesting system for future residential air conditioning applications. For instance mini-VRFs are the one that have to be taken into account in this work.
The heating source of VRF systems can be divided into Air-source and Water-source (Ground-source). Water cooled VRF systems are attracting increasing attention. They combine water-source heat pump technology with existing air-cooled VRF technology.
Furthermore some countries have recognized VRF systems as a green technology and have introduced subsidies for VRF installations.
The refrigerant mostly used is R410a.
Price for a mini VRF system is higher than a multi-split system considering a number of internal units suitable for residential use. The price for an external unit with a power of 12.5 kW for large residential applications (up to 8 internal units) is around 3500 € plus from 400 – 600 € for the internal ones. The installation costs are around 1500€ for the entire system.

Considering a VRF system for a residential application, with five internal units the price is around 9000 €.

Types of VRF systems

VRF systems can be used in three possible ways:

- Cooling only: The system can work in the only cooling configuration.

- Heat pump: The VRF heat pump configuration permits the heating or cooling of rooms but not simultaneously.

This is also known as two-pipe system. The heat pump configuration is also reachable with multi-split systems. However heat pump VRF systems unlike multi-split systems have applications addressed to bigger buildings (commercial or tertiary sector), which require cooling or heating during the same operational period.

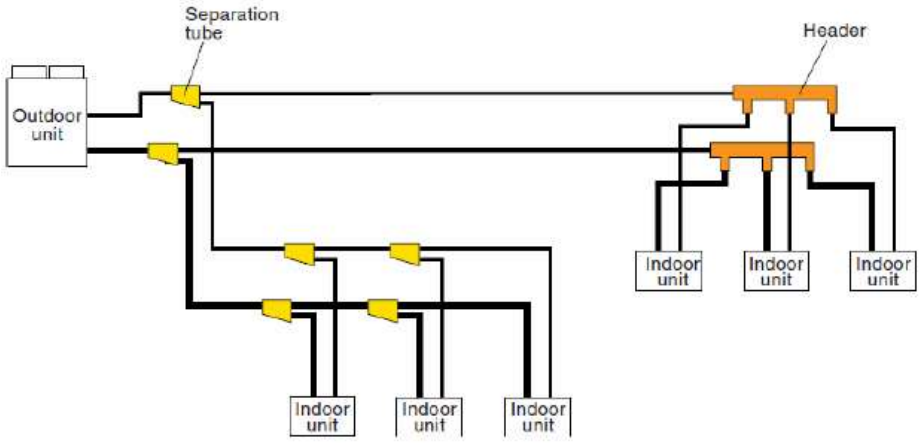


Figure 2.16: Two-pipe system - source HVAC Variable Refrigerant Flow Systems, A. Bhatia

- Heat recovery VRF: The VRF-HR system can satisfy heating and cooling needs of different rooms in the same time. Each indoor unit is fed by three pipes (liquid line, hot gas line and a suction pipe), a solenoid valve is used in each indoor unit to control the fluxes. If one indoor unit is requiring cooling the solenoid valve will open the liquid line and the suction pipe acting as an evaporator while if an indoor unit is asking for heating the valve will open the hot gas line and the liquid line.
Part of the heat absorbed from the cooled zone can be used to warm the refrigerant which will feed the indoor unit requiring heating. This is a particular case which occurs usually for a few times during the year but it causes remarkable energy savings.

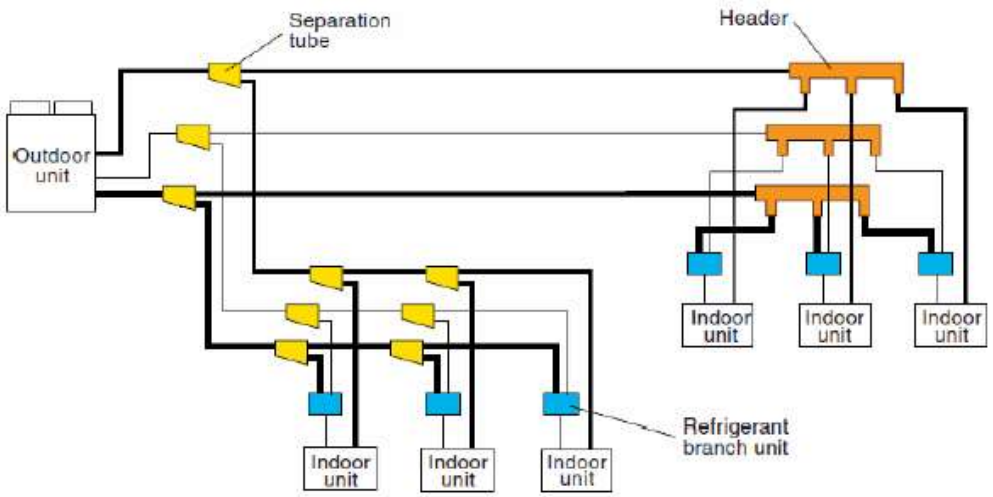


Figure 2.17: Three-pipe system - source HVAC Variable Refrigerant Flow Systems, A. Bhatia

- *Windows-Through the wall air conditioners*

Also known as single packaged units while the elements that compose the system are all assembled together to form a compact solution.

The system can be mounted through the wall or inside the window, all the components of the system are the same as for single-split units: compressor, condenser, expansion valve and evaporator. One side of the unit is in contact with the outside air which includes the condenser, the indoor side of the system is exposed to the internal air, the evaporator. The two sides are separated by an insulated wall which reduces heat losses.

Figure 2.18: Through the wall and window unit's examples

The through-the-wall type is usually placed under or above a window or above a door. The two types are very similar, the window type is designed to be installed in a window opening and the wall one need an opening in the exterior wall.

These systems are widespread in North America, USA has the largest market in term of sold units. It is a not so common solution in Europe, indeed in almost all the European markets has been losing market shares during last few years.

These air conditioners are used only for cooling applications, the heat pump version is very rare. Latest versions of the system are all inverter driven.
The most used refrigerant is R410a.
Complete price for a single unit, taking into account also installation costs is from 400 – 1000 €.

Movable:

- *Movable single duct units:*

All the components of the refrigeration cycle are all assembled in one single unit placed inside the room, only the condenser is connected to the outside through a duct with whom removes the hot air from the inside.

Figure 2.19: Movable single duct unit

They are usually movable units, and it is necessary to consider a hole in a window or in a door in order to seal the duct and not allow infiltration of outdoor air.
The energy consumption is quite high, and it strongly depends on outdoor air temperature, furthermore indoor units are quite bulky inside a room (they are not placed to the wall or ceiling) and they can be also annoying from an acoustic point of view.
R410a is the refrigerant generally used.

- *Movable double duct units (it can also be fixed):*

The double duct unit is very similar to the single duct one, except for the air used to cool the condenser, in this case, is taken outside the room through one of the two ducts while the second duct is used to throw out the hot air.
It is also possible to find the fixed version of these systems, however two permanent holes on the wall are needed.
The double duct configuration is the evolution of the single duct one, energy performances are improved.
Both single duct and double duct units are commonly used in the residential sector with a virtually nil impact on the building. They are considered very interesting solutions in not owned dwellings or they also can be chosen as cheap choices.

Figure 2.20: Movable double duct unit

The problems are in particular related to the encumbrance of the unit inside the room.
The system is able to control temperature and humidity levels.
Prices[2] for a movable unit with a power around 3 kW are in the range 350 – 600 €. There are no installation costs.

- *Moveable split units:*

As mentioned before for fixed single-split units, the term split is used to describe the installation of the system. This case makes no difference, the evaporator and the condenser are separate, however, unlike single-splits, the indoor unit is movable and the outdoor unit can also be movable or fixed.

Figure 2.21: Movable split unit

It is the less common version of split units, in Europe are almost not used. The price is lower than fixed splits, but the dimension of the indoor unit is bigger and the compressor has higher energy consumption. Inverter driven compressor are not used for this configuration.
These systems control temperature and humidity inside the room as classic splits do.
Also in this case R410a is the most widespread refrigerant. Price is around 600 €.

[2] Prices are very similar both for single duct and double duct units.

2.4.2 Central Air Conditioners (CAC):

In this category are considered those systems that do a centralized air treatment, and with the assistance of ducts send the primary air to the different rooms.
In spite of Room Air Conditioners (RACs) that treat completely the air inside the room, CACs handle outdoor air, and supply the various rooms with renewed air.
The conditioned air is transferred to the rooms through ducts and the air distribution is managed by centrifugal fans.
Central air conditioners can provide all different types of air treatment: heating, cooling, humidification, dehumidification, primary air treatment and heat recovery.
Considering cooling applications, it is possible to distinguish two main categories of central air conditioners.

- Packaged Air Conditioners:

The word "Packaged", as mentioned above, is related to the fact that all the components of the refrigeration system are in the same block. The complete system is composed by a single unit factory assembled, may be placed outside of a building or on the top of it (rooftop unit), or even in a special room (indoor package).
The main components of the system are:

- Compressor: Usually scroll type compressor.
- Air-cooled or Water-cooled condenser: Air-cooled condenser is usually adopted for smaller capacities.
- Electrical panel.
- Expansion valve: thermostatic and electronic.
- Air filter.
- Return Air grill.
- Evaporator coil.
- Evaporator fan.
- Heating and humidifying components: Dehumidification (summer operation) and Humidification (winter operation).

Packaged air conditioners have the same working principles as packaged air conditioners mentioned in the previous chapter, but capacities into play are higher.
These are systems usually adopted in tertiary and commercial sector application not in the residential sector except for big buildings with several users.
The following classification of package units is due to the installation mode.

- *Outdoor packaged:*

- *Indoor packaged:*

- *Rooftop:*

Cooling capacity ranges are from 15 to 80 kW, they are not technology widespread in the residential sector, mainly in the commercial one.
Packaged air conditioners can also be applied in the residential sector in specific conditions, the power of the units is basically high, it means that the system has ho supply multiple residential dwellings.
They can be in chiller configuration (only cooling) or in heat pump configuration (cooling and heating). In the following chapter will be analyzed heat pumps and chillers. R410a has replaced by R407C in the last years.

- Ducted-split units:

Ducted-split systems consist of an outdoor unit and an indoor unit. The system is split in two sections: the condensing unit is located outside the dwelling while the indoor unit, where the evaporator is, is placed within the ceiling or under the floor. The two sections are connected with two pipes of refrigerant and with one electric cable.
Ducted-split units can provide cooling and heating with a complete control of temperature and humidity levels.
The indoor unit is connected to a flexible ducted network assigned for the air distribution. Terminal elements (vents) are located throughout the rooms.
Inside every room are a vent for the air distribution and often also present a nozzle for the air recall (the air recall can be done room by room or centrally). The air is taken from the room to the centralized evaporator and sent back to the room after undergoing treatment.
A thermostat is in contact with the central unit which changes the air flow on varying of climatic conditions inside the room.
These systems can be installed in new buildings but also in existing ones.
Ducted splits is a very interesting cooling application for places which can afford ceiling installation above false ceiling and also require optimum air distribution. Distributors are also well integrated in the false ceiling and they do not have aesthetic impact into the indoor environment.
It is a solution usually adopted for cooling and heating needs thanks to the possibility to reverse the cycle.
They are considered to be the quietest air conditioning system, however it is important to place indoor unit (it is the noisiest device of the system) in an appropriate position, in the ceiling or under the floor.
Ducted splits can be very expensive more than multi-split ones and they have also higher gas emissions than non-ducted split units.

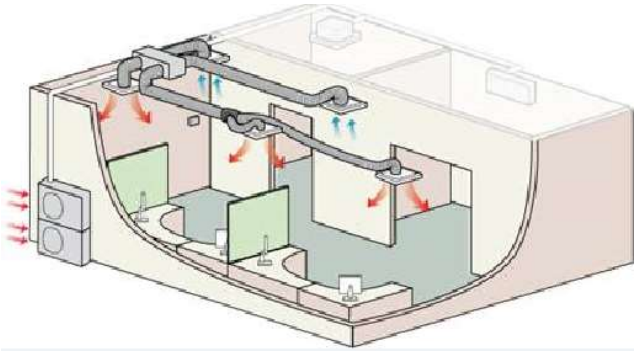


Figure 2.22: Ducted multi-split unit

This air conditioning system is very widespread in particular in North America. The presence of the ducts require big dimension buildings, and as for all-air systems, North American market is potentially a better market. R410a is the most common refrigerant.

2.4.3 Considerations on RACs

Split systems are for many reasons the best cooling technology on the residential market. Price, installation procedure, dimensions, temperature and humidity control are the best qualities of this technology.
A further aspect is the awareness of consumers of this technology. It is also possible to buy a split unit in a simple appliance store.
All split systems available on the market are in heat pump configuration, this allows them to be a possible solution even as a heating systems, a potential alternative in those countries where heating demand is limited.
Despite nowadays splits for heating applications are still not convenient for the high operative costs, however they could be in the future a very interesting alternative.
Splits with inverter driven compressor have been improving their efficiency and for multi-split units the inverter technology allowed them to have control room by room. VRF systems have been also a very big step ahead.
Every unit can be placed in different places in a room, however the air flux produced by the internal unit is considered annoying by many consumers.

3. AUXILIARY COMPONENTS OF A COOLING SYSTEM

3.1 INTRODUCTION

All the air conditioning systems described beforehand are those proposed by the standard EN 15243:2007, however they cannot be considered as proper complete systems. Regarding hydronic systems for instance or all-air systems were not taken into account the potential sources with which is possible to generate cool (or heat).
Furthermore, as previously mentioned in the description of hydronic systems and Residential Air Conditioners (RACs), in the first case it is necessary, especially in certain climatic zones, a humidity control and in addition a primary air control.
In the RACs case, especially for multi-splits, ducted-splits and VRFs sometimes it is possible to add a system for air renewal.
In this paragraph the target is to describe those elements which are fundamental for a complete operation of cooling systems. Moreover, the purpose is also to illustrate additional components, which allow a control over multiple parameters and reach higher comfort levels.
It is as much important to consider these components because information about them can also clarify how air conditioning systems could evolve depending on the contribution that auxiliary components produce.
In particular will be described three components: Dehumidifying and primary air systems, Chillers and Heat Pumps.

3.2 DEHUMIDIFIERS AND PRIMARY AIR SYSTEMS

In the air conditioning market between all the systems taken into account the only one category potentially able to provide for: temperature, relative humidity, and renewal air control is the all-air systems one.
Hydronic systems for instance, especially in specific climatic zones particularly humid ones, require a moisture control. Always more often the system which provide for the humidity control can do also renewal of air.
RACs on the other hand are systems able to have control over humidity and temperature levels inside a room, so when necessary they can be matched with systems which supply fresh air.
It is possible to define the combined application of hydronic systems or a RACs with an additional system, integrated systems.

The different configurations of integrated systems will be classified considering or not the presence of a plant which provides primary air to the ambient.

3.2.1 Dehumidification systems without primary air control

Isothermal dehumidifier: It threats the air inside the room reducing its humidity, maintaining neutral temperature levels. It is usually matched with hydronic radiant systems and also require hydronic feeding.

Dehumidifier Air-Conditioner: the air inside the room withstands a reduction of temperature and a reduction of humidity. Hydronic radiant systems are matched with them and also in this case DACs require hydronic feeding.

The dehumidifying unit is composed by two batteries powered by the water from the radiant system.
An alternative to these systems is represented by fan coil units (to take care of the latent load) to be matched with radiant systems.
Fan coil units produce also sensible load and sometimes it can be a problem while it would be in addition to that supplied by the radiant system.

3.2.2 Primary air control dehumidification systems

Dehumidification systems without primary air control can be of different typologies and can be matched with different cooling systems (radiant, fan coil, some RAC).
This allows to obtain higher comfort values for each cooling system and it even permits a control over all the ambient parameters, moreover a better quality of the air.
These systems are AHUs which are able to filter, cool (even heat), and control the humidity of the inlet air. They can be also coupled with heat recovery units in order to be able to improve their efficiency.
In this category is also mentioned a filtered primary air system which does not have effect on the moisture of the air while it is matched with system that control themselves the humidity.

Filtered primary air: Outdoor air is inserted inside the rooms through a Mechanic Control Ventilation (MCV) unit which filters and takes care of the air replacement without doing any dehumidification treatment. Fan coil units and some RACs (multi-splits, ducted splits, VRFs) can be integrated with this primary air filtration unit.

Isothermal primary air dehumidifier: primary air humidity is reduced, maintaining the same temperature levels, the air can be or not filtered. Radiant systems and fan coil systems are matched with these units.

Primary air conditioner: Temperature and humidity levels are reduced and also the primary air is filtered. With this system it is possible to have a complete control over all comfort parameters.

The illustrated systems are used to increase the cooling effect and improve comfort conditions of an ambient.
In some cases their application is essential, for instance in some climatic zones it is impossible to apply a radiant system without a dehumidifying unit, and it all depends on the dew point temperature of the air.
While in other cases, the application of these additional elements has the purpose to make the system more complete. Prices for these systems are from 1000 – 2500 €.

3.3 HEAT PUMPS

3.3.1 Introduction

In this work the category so called “Heat Pumps” is to be understood as those machines which are able to provide heating and cooling to a terminal element without relying to other additional components.

It is important to notice that also other systems previously described in the category “Residential Air conditioners” are reversible heat pumps. However, it has been made the choice to separate the description of the two categories: in one case “Residential Air Conditioners” represent a complete system, whereas in this case the heat pump constitutes a part of a complete system.
Heat pumps are energetically speaking one of the most efficient systems for residential and commercial air conditioning, are machines able to move heat from one source at a lower temperature to another at a higher temperature, increasing the temperature of the source.
To obtain this effect, it is necessary to supply to the pump a certain amount of energy, generally electric.
According to the European directive RES (Renewable Energy Sources), if the thermal energy captured by the heat pump exceeds considerably the energy essential for its operation, it can be considered renewable.

A heat pump is composed by a compressor, a condenser, a lamination valve and an evaporator, all connected by a closed circuit where a special fluid, depending on the temperature and pressure conditions, becomes liquid or vapor.
The condenser and the evaporator are two heat exchangers, where the fluid flows. The fluid removes heat from the evaporator and transfers it to the condenser.
The cycle can be inverted and each heat exchanger can work as a condenser or as an evaporator.
In general, heat pump efficiency improves as the difference between the temperature at the evaporator and the temperature at the condenser becomes smaller.

Heat pumps can be used for cooling applications, in addition to heating applications. The thermic cycle behind as for cooling as for heating is the same, in the case the same heat pump is used for both applications it is called reversible. From now on it will be used the term “Heat Pump” for reversible ones.

There are two main typologies of heat pumps:

- Compression heat pumps
- Thermal compression or absorption heat pumps

The two typologies differ from each other depending on how the pressure of the fluid is increased. Mechanically for compression heat pumps and thermally for absorption heat pumps.

3.3.2 Electric heat pumps

The most common heat pumps are electric driven ones. The compressor is electric powered and it is the key component of the system. Compressors can be alternative (piston) or rotary (screw, swing, and scroll), the second ones are the most widespread. Innovative compressors are all based on inverter technology.
RACs are all compressor driven heat pumps.
Compression heat pumps are the most common, while they can be coupled with all the terminal elements. Temperature range is very ample.
Radiant systems are all fed by compression heat pumps

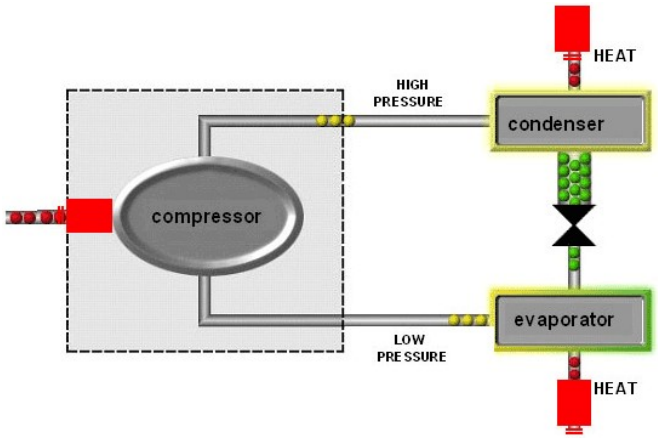


Figure 3.1: Compression heat pumps - source ROBUR

Cooling capacities ranges are from a few kW to several MW. In this category are considered in particular small-medium capacity heat pumps, those can be applied in the residential sector without considering RACs in this category.

There will be considered only those heat pumps that can be matched with hydronic systems (fan coil units or radiant systems) and with all-air systems.

In general, for a single family house capacity range is under 20 kW.

Average values of COP are around 3-4.

3.3.3 Absorption heat pumps

Compared with classic electric compression heat pumps, where the compression is mechanically activated, in this case the compression is thermally driven. A heat generator warms a fluid mix refrigerant/absorbent, it originates the separation of the fluids and the compression is activated.

The other components are the same as mechanically driven heat pumps.

The heater is fed usually with natural gas. This is a very interesting solution as substitute for gas boilers.

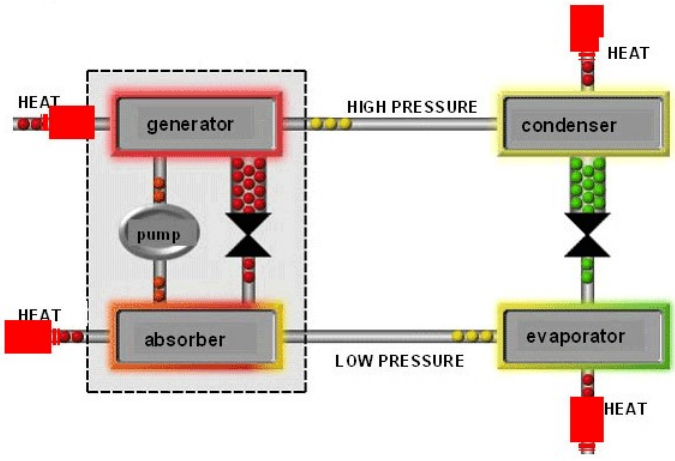


Figure 3.2: Absorption heat pumps - source ROBUR

It is not advantageous to match adsorption heat pumps with radiant systems, compared to electric driven ones are a bit more expensive and temperatures reached with the boiler are not suitable. Fan coil units and AHUs are in on the other hand good applications.
Absorption heat pumps provide heated and cooled water to terminal elements and also can take care of domestic hot water.

3.3.4 Available sources

The heat pump can cool or heat an ambient, it can do it having effect directly on the air inside the dwelling or through an intermediate fluid, usually water. The intermediate fluid carries the thermal energy which will be transferred or absorbed directly to or from the air through heat exchangers (fan coils, radiant systems, etc…).
Innovative systems which exploit intermediate fluid (water) could also produce Domestic Hot Water.

A heat pump can exchange thermal energy, to the outside, directly with the air, or with an intermediate fluid, water or glycol water, which will exchange heat with the source.
The available sources are three:

1. AIR: Air has the advantage to be available everywhere. However the efficiency of the pump strongly depends on the outside temperature, and if the difference between the temperature of the source and the indoor temperature is substantial the efficiency collapses especially in winter operation.

2. WATER: Water guarantees better performances, while it is not much affected by the influence of external climatic conditions. However water requires higher costs for the system.

3. GROUND: Ground has almost the same temperature for all year, and it is the best that can be exploited. It is necessary to install under the ground vertical or horizontal heat exchangers, expensive and which require several space to be installed.

Heat pumps can be classified depending on the combination between external source and the internal operative effect, if it is directly the air otherwise is an intermediate fluid (water) to be cooled or heated.

- AIR-AIR heat pumps: As previously mentioned, with this typology we are referring to packaged or split systems. An external unit exchanges thermal energy with the air and transfers it to the internal one (they can be separated or in one single block). Roof-tops, indoor Packaged, etc. are also Air-Air heat pumps. They can also feed AHUs.

- AIR-WATER heat pumps: Hydronic systems belong to this category, the air is exploited as external source. These systems can cool or heat water which is used to feed terminal elements as fan coil units, radiant systems or AHU.
Rooftops, indoor packaged, etc. belong also to this category.

o AIR-WATER and WATER-WATER heat pumps: Take advantage of the water as renewable source. The water can be superficial or groundwater.

o GROUND-WATER heat pumps: It is nowadays a technology that is having more and more attention. In particular in northern countries this typology of heat pumps in very widespread.

Electric driven heat pumps can be configured using all the sources typologies, while absorption ones can take advantage exclusively of the air.
Heat pumps are considered renewable energy sources and several European countries have supported through incentives the diffusion of them.
It is important to notice that electric driven heat pumps are the most widespread and percentage of absorption ones is very small.

In cold climates, such as Northern European countries, where outdoor temperatures may fall to around -40 °C, air sourced heat pumps as ATW ones, in winter conditions, are not able to compete with boilers.
To compensate this weak point, air conditioner manufacturers have developed hybrid ATW heat pumps systems that also can use a gas boiler in addition to the pump when outdoor temperature is very low.
ATW heat pumps are considered to be the most promising technology and all-in-one ATW models heating, cooling and sanitary hot water production are the latest products on the market.

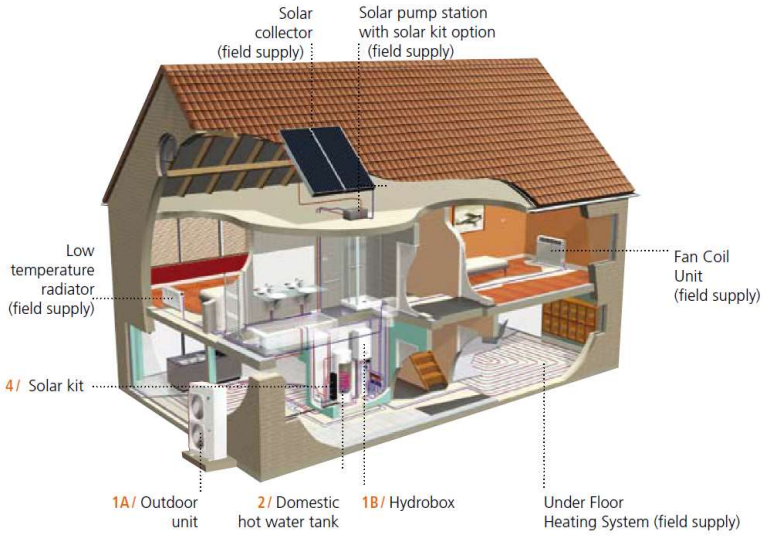


Figure 3.3: ATW Heat Pump, Heating, Cooling and SHW, matched with radiant system and fan coil units – Source DAIKIN (Daikin Altherma)

Solar thermal collectors are increasingly integrated into heat pump systems.
The European ATW market is projected to expand in the next years. Two market trends, according to JARN, are expected to show particular growth, more compact ATW products for residential use and larger capacity ATW products for commercial use.
Furthermore, the insulation capacity of houses is rising, ATW heat pumps that produce low temperature hot water in heating operation, for radiant systems for example, will move towards to smaller capacity heat pumps.

Indeed, many manufacturers are lowering the capacity of their product range down to about 5 kW and adding more compact models.

R410A is the dominant refrigerant in the European ATW market, R407C is also used. CO_2, ammonia and propane are in future perspectives interesting refrigerants as substitutes for traditional refrigerants.

Heat pumps compete with prominent and widespread technologies, depending on the required functionality, competitors are gas-, oil-burners, direct electric heaters or biomass burners and even chillers.

Incentives are essential, however the main driver for a deep impact of electric driven heat pumps is the price of electric energy compared to the price of Natural gas while operating costs of heat pumps and gas boilers depend on the prices of electricity and gas.

Price for Air/Water heat pumps is in the range of 3,500 - 4,000 € for a unit with a power around 5 kW.

Smart heat pumps, which can intelligently work connected to a smart grid have been already tested in several pilot projects among Europe, for instance "Lechwercke's – Smart Operator", and also the Fraunhofer ISE has been planning a large scale test. It would be very important for an extensive use of this technology and for a smart connection of the units the flexibility on electricity prices, allowing to a user to follow the electricity price's curve and to choose when to consume energy.

Among Europe, for instance in Italy, in Germany and in other countries, Natural Gas is the principal heating source, the relative pricing of fossil fuel to electricity is crucial to the success of electrically driven heat pumps.

This relative pricing is defined as the Energy Price Ratio (EPR):

$$EPR = \frac{EP}{\mathrm{FP}}$$

EP = Electricity price [€/kWh]

FP = Fuel price [€/kWh]

The lowest ratio indicates a favorable price structure to electric driven heat pumps while the highest one indicates a price structure in favor of gas driven sources.

3.4 CHILLERS:

From a technical point of view chillers can be considered heat pumps but for the only cooling application. The operative cycle is the same as for heat pumps, and also chillers can be electric driven and use a mechanical compression for the operating principle or thermally driven absorption chillers.

Chillers can be air-cooled, or water-cooled, it is in practice impossible to find a ground based chiller even if it could technologically speaking achievable. In general Air-cooled condensers are the norm except for large installations.

3.4.1 Electric driven chillers

The compressor is electrically powered, and depending on the capacity it can be of different typologies.

We will consider in this case only mini-chillers, typically dedicated to residential applications and commercial buildings.

These chillers can supply fan coil units or radiant systems but also AHUs.
New solutions for technology improvement are:

Free cooling:
An additional air to water heat exchanger can be added to the machine, it can reduce energy consumption. Typically it is used a mix of external air and recirculated air to cool air temperature reducing the chiller operation.
This is a solution also implemented for heat pumps.

Evaporative cooling:
Most of chillers use air cooled condensers to reject the heat from the dwelling. Evaporative cooling is a very interesting technology for this application.
An evaporative pre-cooler can reduce air conditioner load by cooling the air that surrounds the condenser. The efficiency of the chiller can be increased.
The description of the mechanism is illustrated below.

Price for electrically driven chillers with a power in the range 5-6 kW is around 3000 €.

3.4.2 Absorption chillers

The heat generator can be powered directly using natural gas or indirectly exploiting hot water from a renewable source (Solar cooling), the latter in the residential sector is practically not applied.
Medium capacity absorption chillers are in heat pump configuration, moreover solar cooling is a growing technology, especially for industrial applications.
Absorption chillers can be easily matched with fan coils, while, as for heat pumps, with radiant systems are not economically speaking a good solution. This is related especially to the temperatures reached by the heat generator.
Absorption chillers have a very low market share compared to electric driven ones.

4. IMPACT OF F-GAS REGULATION ON AIR CONDITIONING SYSTEMS

4.1 INTRODUCTION

In the Residential Air Conditioner category are contained different systems which have all behind a refrigeration cycle. The use of refrigerants is regulated by the F-Gas Regulation according to the RES Directive.

The revision of F-Gas Regulation became law on January-1-2015 has as its targets the refrigerant fluids used on the systems described in the category just mentioned.

During the last years the on-going revision of F-Gas regulation has stimulated considerable research and development through new refrigerants: natural refrigerants (CO_2, ammonia, hydrocarbons) and also new synthetic refrigerants.

In this paragraph will be analyzed which are these refrigerants, the consequences that the regulation entails, future solutions and alternatives and the impact on the market.

4.2 THE F-GAS REGULATION

The European Commission, in November 2012 proposed to update the Regulation 842/2006, the result is the Regulation 517/2014 of the European Parliament published on May-20-2014 and applicable starting from January-1-2015.

The 2006 Regulation had two main criteria

- Internal market.
- Environment.

The new Regulation has only one criteria related to the environment. Everything about rating plate, control and limits are established on environmental base. Its purpose is the reduction of greenhouse effect emissions.

The regulation involves the so-called fluorinated greenhouse gases: HFCs, PFCs and SF_6. Not all the limitations are applied to all types of fluorinated gases.

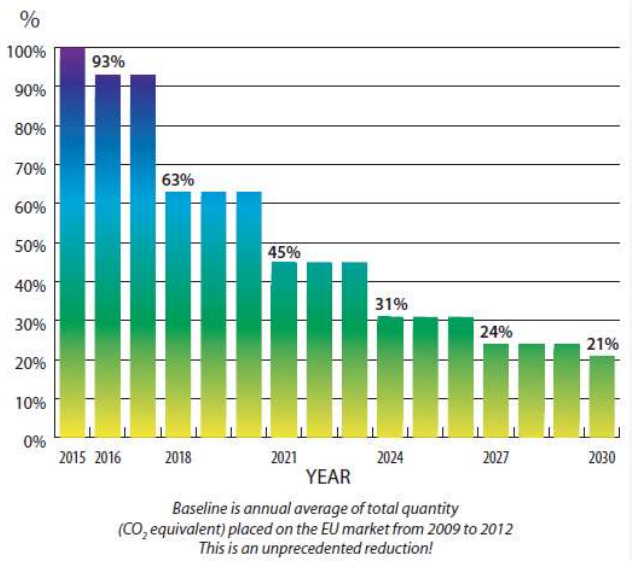


Figure 4.1: HFCs gradual reduction expressed in CO_2 equivalent

The gradual reduction for instance is applied only at the HFCs not at the others.

HFCs are not responsible for the reduction of the ozone layer, however most of them present an elevate Global Warming Potential (GWP)

The 2014 regulation adds additional requirements aiming the reduction of F-gases emissions and/or their GWP value.

The most important aspect of the 2014 F-Gas regulation is the so-called "gradual reduction" which will change deeply the approach of the industry with F-gases.

The HFC quantities are expressed in CO_2 equivalent, quotes will be assigned to refrigerant producers or importers and these quotes will be reduced gradually until 2030 expecting a 79% reduction of HFCs application.

The quotes are expressed in CO_2 equivalent, it means that the higher the GWP of a refrigerant is, higher would be the quantity of CO_2 equivalent for a fixed amount of kilograms and consequently higher would be the necessary quote.

The Regulation is not conclusive, the European Commission can still change some important elements, and has also the assignment of monitoring the effects of the gradual reduction.

Member States can introduce more restrictive regulations in accordance with the European regulation.

If operators/companies do not respect the provisions of Regulation, they will be subject to penalties.

The European Commission, with the "gradual reduction" and the quotes assignment, grants market flexibility and contemporaneously it fosters innovation towards lower GWP values refrigerants.

In addition to this, starting from 2020 refrigeration systems with an amount of refrigerant over 40 tons of CO_2 equivalent could not be subject of maintenance intervention with HFCs with a GWP value over 2500. It means that maintenance intervention are also restricted.

4.3 REFRIGERANTS IN THE AIR CONDITIONING INDUSTRY

The F-Gas Regulation considers systems which contains fluorinated gases or mixes containing these gases in refrigeration circuits.

In air conditioning systems fluorinated gases are widely used, for instance R-134A (HCF) and R-410A or R-407C, both HFC mixes. In addition to HFC, in more dated systems HCFC refrigerants are still used as R-22 gradually eliminated from the market thanks to the Montreal Protocol, responsible for the reduction of the ozone layer.

HCFs R-134A, R-410A or R-407C are mainly used as refrigerants in heat pumps while in split systems and chillers R-410A is the most common solution.

Always more often are used other refrigerants as R-744 (CO_2), R-600a (isobutene), R-290 (propane), R-1270 (propylene) and R-717 (NH_3) and also R-32 (HFC).

	M (kg/kmol)	Flammability	GWP	Definition
R-22	86,5	NF	1780	HCFC
R-32	52	LF	675	HFC
R-134a	102	NF	1430	HFC

R-410a	72,6	NF	2088	HFC mix
R-407C	86,2	NF	1774	HFC mix
R-744 (CO_2)	44	NF	1	
R-600a	58,1	F	~20	HC
R-290	44,1	F	5	HC
R-717 (NH_3)	17	LF		
R-1270	42,1	F		HC
R-1234yf	114	LF	<1	HFO

Table 4.1: Characteristics of different refrigerant fluids

In addition to HFCs and to natural refrigerants, Hydrocarbons (HCs) for example, new synthetic refrigerants are available on the market, the most famous one is the HFO 1234yf, from a technical point of view it is a very interesting alternative to R-134a, but it is very expensive and latest studies have demonstrated some problems with it in air conditioning applications.

4.4 F-GAS REGULATION IMPACT

The gradual reduction of CO_2 equivalent quotes will be leaded by the progressive entering into force of the F-Gas regulation.

The key steps of the regulation are the following:

100%	January-1-2015	• Entering into force of the new regulation. Residential fridges and freezers HFC driven with GWP>150 are banned.
63%	January-1-2020	• Commercial fridges and freezers (hermetically sealed) HFC driven with GWP>2500 are banned. • Fixed refrigeration systems with GWP>2500 (except for systems for refrigeration of products T<-50°C) are banned. • Portable refrigeration systems (hermetically sealed) HFC driven with GWP>150 are banned.

		• HFC with GWP>2500 used for maintenance of refrigerant systems with more than >40 tons equivalent of CO_2 except for: ○ Refrigeration of products T<-50°C. ○ Military uses. ○ Until 2030 for HFC regenerated and recycled.
45%	January-1-2022	• Commercial centralized refrigeration systems (Multipack) with capacity>40kW HFC driven with GWP>150 are banned (except for gas used in a primary circuit with GWP>1500 are banned, for example R-134a for the first stage and CO_2 for the second stage). • Commercial fridges and freezers (hermetically sealed) HFC driven with GWP>150 are banned.
31%	January-1-2025	• Split air conditioning systems with less than 3 kg containing or driven by HFC with GWP>750 are banned.
1%	January-1-2030	• Regenerated and recycled refrigerants with GWP>2500 used for assistance and maintenance to more than 40 tons of CO_2 equivalent are banned.

4.5 CONSEQUENCES OF F-GAS REGULATION IN THE AIR CONDITIONING MARKET

Looking at the key steps of the regulation, starting from January 1 2015 there will take place a gradual reduction and the substitution of HFCs with lower GWP refrigerants. From a general prospective, the tendency is that the industry is moving toward natural refrigerants or HFO refrigerants.

The F-Gas regulation is influencing air conditioning products, however Companies are making progresses on new products.

There is not a unique solution, every application requires a different refrigerant. For instance Danfoss has made a research on future refrigerants applications from which it appears that CO_2 would be the most used refrigerant in the industrial refrigeration followed by NH_3 (toxic, it requires more security measures).

Hydrocarbons will have an important role in the next future especially in low charge refrigerant systems.

HFCs will not disappear, it is expected a reduction on the usage, moving through lower GWP HFCs, for example HFOs R1234yf (selected by the car industry as substitute of R134a) and R1234ze (candidate as replacement of R134a in big centrifugal chillers).

Alternatives to fluorinated refrigerants continue to be sought, no one has yet found the perfect refrigerant in terms of performances, environmental impact, and price. However several replacement candidates are taken into account, for different applications.

A list of refrigerants follows:

CO_2:

There are several applications where CO_2 could be an attractive solution, for instance the industrial refrigeration where it is already used or in combination with ammonia.

The cost is very low, and the price of the systems with CO_2 as refrigerant is getting closer to the price of traditional systems with HFCs inside.

NH_3:

Ammonia is a very well-known refrigerant used in particular in big industrial systems. It has very good thermodynamic properties, however it is toxic, flammable and materials that have to be used to manage it are very particular. That's why it is not used in the commercial sector.

NH_3 is a natural refrigerant with a GWP equal to zero and it is very efficient.

Ammonia is very cheap, but systems with ammonia are quite expensive since there are the necessity to use steel pipes, security devices and other expensive components.

HYDROCARBONS (R290, R600a, etc…):

Hydrocarbons belong to the family of natural refrigerants and have a GWP close to zero. They can be used in several refrigeration applications and air conditioning.

HC are flammable, for security issues there are several standards and regulations that regulate their applications.

R600a (Isobutene) is mostly used for residential refrigeration while R290 as substitute of R134a, R404A or R410a (heat pumps, dehumidifiers, room air conditioners, etc…).

R1270 (propylene) used as substitute of R22 and R502 in commercial refrigeration big air conditioners, chillers, etc….

HFCs & HFOs:

They are synthetic refrigerants and they represent a large selection of single components or mixes. R134a for instance is a single component while the main mixes are R404A, R507, R407C R410a and R32.

They have all a GWP value in the range 1400 – 2100, except for R32 (675).

R1234yf and R1234ze have a lower GWP value, however they are very expensive and they represent the limit for synthetic refrigerants that can be reached.

HFCs are the solution during the transition driven by the F-Gas regulation while HFOs could be used for limited applications.

LATEST NEWS:

August 7, 2015 - JARN

SPAIN: Frigicoll, a major supplier of air conditioning and refrigeration equipment in Spain, has introduced an air conditioner using R32 refrigerant under its Kaysun brand.
This latest addition to the Kaysun range of domestic splits is the first time an air conditioner using the non-ozone-depleting, lower GWP R410A alternative, has been made available in Europe by anyone other than Daikin.

August 25, 2015 – JARN
Residential heat pump Eco Cute – CO_2 driven for instance in Japan has in the last years attracted attention.

5. THE GLOBAL AIR CONDITIONING MARKET

5.1 INTRODUCTION

Before addressing in detail the Air Conditioning Market, it is interesting to introduce what is the Global situation regarding the HVAC Market.

It is very important since it describes the state of the different global markets. The share that Air Conditioning has for instance. Moreover it allows us to observe which other sectors (as Heating for Europe for example) have a greater impact.

The following figure describes the Global HVAC Market in terms of value where the main four markets are exhibit.

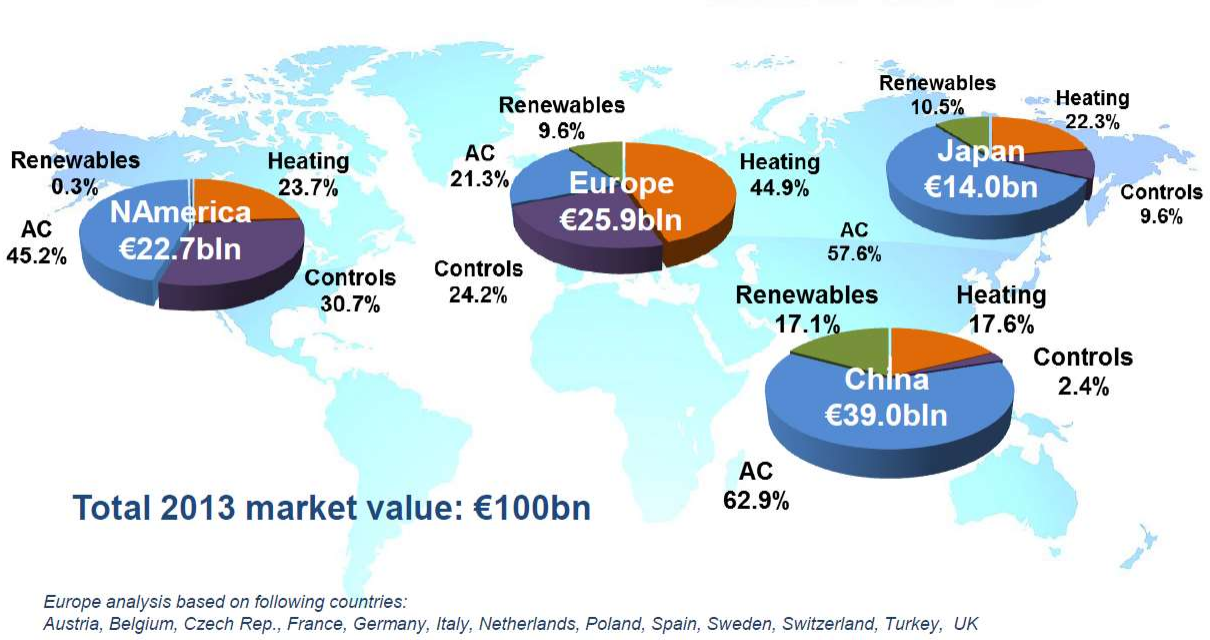


Figure 5.1: Global Major Regions HVAC Market Value – Source BSRIA

Europe is the second biggest market after the Chinese one, it is interesting to notice that around 45 % of the whole market is covered by the Heating sector and 21 % by the Air Conditioning. It is the only market where Heating have bigger importance. This is a very interesting aspect regarding the European market, heating technologies which have already now a big market share and can be also used for cooling applications could have a quite strong impact also in the air conditioning market.

5.2 THE AIR CONDITIONING MARKET

The Global Market for air Conditioners counts approximately 100 Million of units sold in 2013. The markets in China (40 million of units), North America (14.5 million of units), Japan (9.6 million of units) and major European countries (6.7 million of units) represent 70 % of the world market.

Other major world markets: South America with around 7 million of units, 4.6 million of units in the Middle East, other SE Asian countries count 6.2 million of units in 2013 and Africa 2.9 million of units.

China is the world's largest market with around 40 % of the global sales and the largest production base with 80% of the total manufacturing. China has high influence on the other markets.

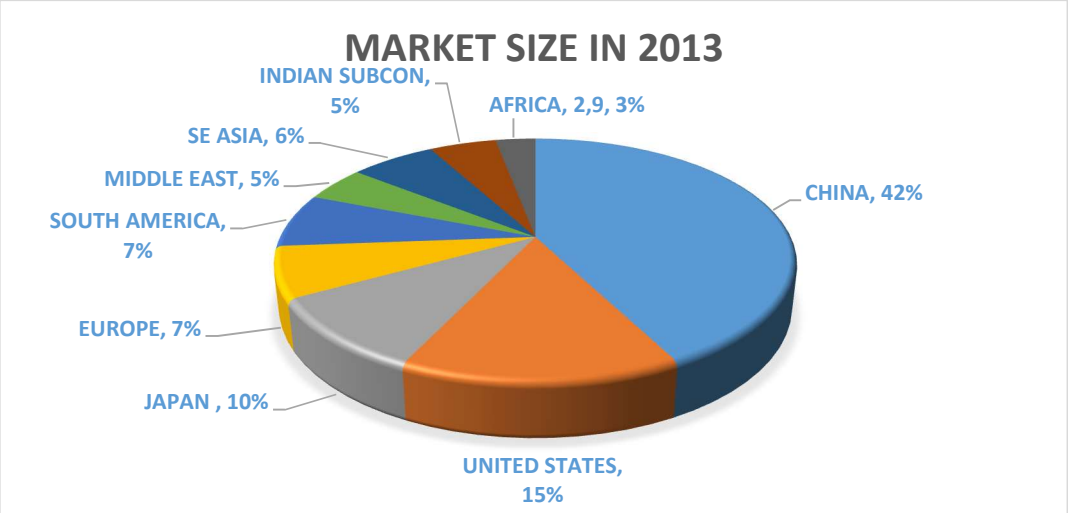


Figure 5.2: AC Market size in 2013, millions of units – JARN 2013

According the Japan Air Conditioning and Refrigeration News, from a numerical point of view, the Global Market for Air Conditioning saw a slowdown in 2012 for the first time in several years, especially in emerging markets as Brazil, the largest market in South America, with 3.2 million of units, who saw a decrease of 1.6 % year after year. Also as India, its market grew for several years until 2011 and turned negative in 2012 with a 9 % contraction. Even Europe, where the Russian market was very promising in 2011 saw a decrease in the latest years.

After an overview of the Global market, it is possible to grasp that there are signs of stability or even better, signs of reduction on the growth.

From an economic point of view on the other hand, the situation is different, the global market is increasing, in 2011 was valued US$ 87.1 Billion and in 2012 US$ 87.5 Billion, while in 2010 was up to US$ 78 Billion.

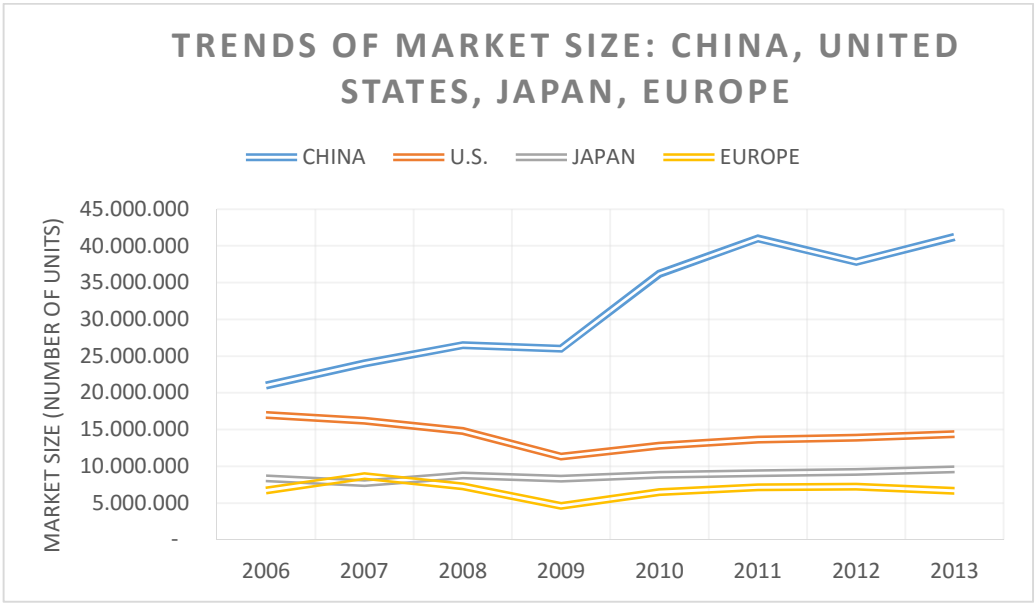


Figure 5.3: Global trends - sources JARN 2012, JARN 2013

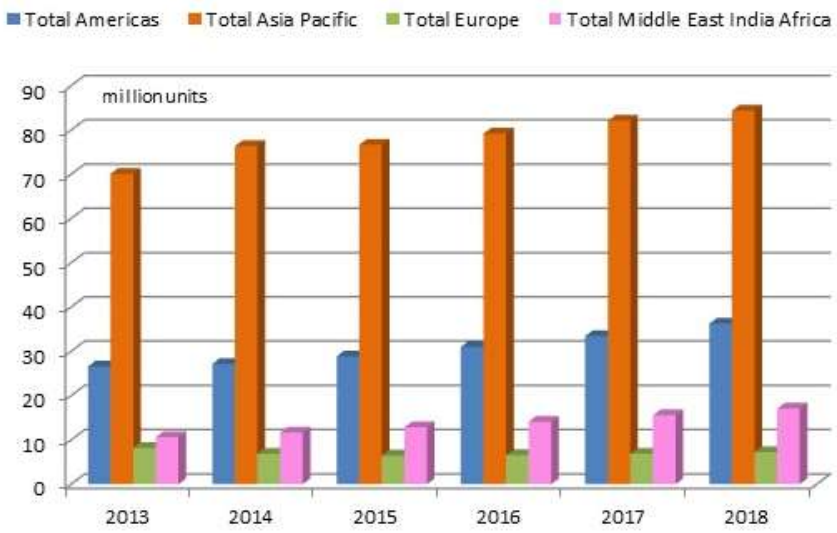


Figure 5.4: Regional Air Conditioning Market in 2013-2018, windows, VRF, Splits, Indoor packaged, and PTAC – source BSRIA

And it still continuing to surge upwards, in 2014 the world air conditioning market reached US$ 97.7 Billion in value, up to 7 % over 2013.

According to BSRIA, much of increase is attributed to the Asian-Pacific region, in particular China but also the Middle East and Africa showed quite an important growth, growing by 9 % in value terms.

The global air conditioning market is recovering from the 2009 financial crisis. The American and the European markets were deeply affected by the economic crisis. America is starting to recover while Europe is still suffering the slow recovery and subsequent slow growth from the financial and the Euro crisis of Eurozone, especially southern European countries.

6. THE EUROPEAN AIR CONDITIONING MARKET

6.1 INTRODUCTION

This chapter aims to study the European residential cooling market, considering the evolution of the European cooling demand of the last decade and identifying how different technologies have modified their market share.

The evolution of the market was studied analyzing data of sales of the different countries taking as reference BSRIA report for Europe of 2005 where there are sales figures for the three years 2003, 2004 and 2005.
For latest data were analyzed the JARN newspapers – "World Air Conditioner Market" from May 25 2012 and May 25 2013 in which they are commented and shown data from years 2011 and 2012 and a prediction for 2013 of the sales in Europe of air conditioning system.
JARN newspapers "World Chiller and Large AC Market" from November 25 2012 and "World Heat Pumps and Key Components" from August 25 2012 were also consulted.
It was consulted the article: "Assessing the market for air conditioning systems in European buildings" to have an overview of the entire European market.
The different systems identified and classified in the technical products chapter represent all the products available on the market for cooling applications, however, inside the just mentioned reports and newspapers not for all of them data are available.
In fact for the category "Residential Air Conditioners" is available clear market data, there are different technical categories which in some cases are grouped as it is possible to see in further chapters.
The products which are included in the reports and in the newspapers are:

- Single-Split
- Multi-Split
- VRFs
- Ducted Splits (Power <=17,58 kW)
- Windows
- Movables
- Chillers (Air cooled and Water cooled chillers with Power <=100 kW)
- Rooftops
- Indoor packaged

It is important to notice that data available for chillers do not well describe the evolution of the products for the residential sector, for instance a high percentage of chillers considered in the study have a too high power for residential applications, especially for single-family houses ones. Though, chillers are the only products present in the reports that can give us information about other technologies for which data is not available, for instance AHUs and FCUs.
Furthermore, has been made the choice to mention the technologies Indoor packaged and Rooftops, despite they are not considered systems which are suitable for European residential applications however for instance in North America is a very common solution, which is the reason why they were considered in the study.

In addition to this, to have more information about the market and to do some assumptions, were enclosed other documents regarding the European heat pumps' market "European Heat pump Market and statistics". In which are also considered air to air heat pumps with main heating function that are practically split units but also air to water or water to water or even ground sourced heat pumps which are just the most common energy sources for those systems for whom clear market data is not available.
Regarding radiant systems, there were some difficulties to collect data for the only cooling application. To overcame this obstacle, when was possible have been considered all the radiant systems sold (heating, cooling, and heating and cooling).
Regarding each Country the residential and the commercial sectors have different market dynamics, moreover market data available considers products sold for residential but also for small commercial applications.
In principle this fact this may lead to errors, however there are insufficient information that can permit a disaggregation of the two markets.

In the first place, it has been made an analysis of the whole European market, considering the KEY 6 European Countries (Italy, Germany, France, Spain, UK, and Greece) plus Turkey and Russia, all together, as representative of all European market.
At a later stage, there will be examined all the KEY 6 European countries, Turkey and Russia individually, plus Norway, Sweden, Finland and Denmark in order to describe the situation in every single country and also to illustrate the situation in the Nordic countries.
The reason why this approach has been chosen is both because the more recent data available forces to use this method, especially in the JARN newspapers was not possible to find more market data for other countries, save the KEY 6 plus Turkey and Russia but also because the mentioned Countries well describe the behavior of the whole European market, for instance the cooling market in Europe is nearly completely (80%) concentered in those countries.
It is also available additional data from the European Heat Pump Association, a Market and Statistics report from 2013, which shows sales statistics and the market development for 22 European countries, it is considered to be the most comprehensive document regarding the European heat pump market.
Moreover, for each country under consideration, there will be analyzed the main external factors that have influenced the evolution of the market.
They were identified in:

- Yearly average summer temperatures: in order to see when and how climate conditions have influenced the market.

- Economic situation of the Country: GDP, GDP pro capita, source Eurostat

- Residential use of energy

- Residential sector: existing buildings, new buildings, single-family houses, multi-family houses, owned houses, houses for rent, etc…, source CIC

In addition to these factors there will be analyzed further features, characteristic of each country.
The purpose of this study is to identify which are the criteria that have led to a certain market distribution of the different technologies in order to understand how the market will evolve in the next future, and also to identify which are the leading factors that have to be taken into account to better understand this evolution.
The market data available for residential cooling systems, generated by JARN and BSRIA used for this study, consider not all the systems' typologies described in the "technology chapter", but only those who have major impact on the market. And for those which are not mentioned in the market analysis done by JARN and BSRIA, the data has been found following other methods and making assumptions, as already mentioned.

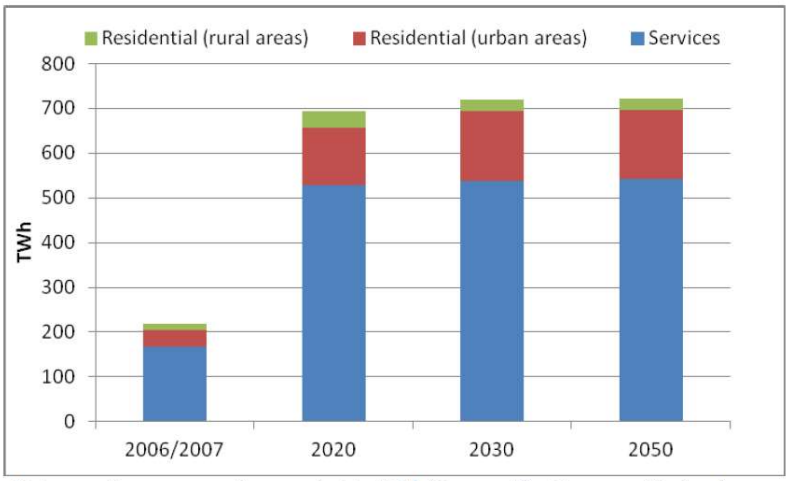
6.2 COOLING DEMAND IN EUROPE

The European air conditioning market can be characterized as a still un-developed field. The saturation of cooling demand is significantly lower than in Asia and USA. Most sources predicted a growth on the demand for cooling in Europe. This entail a significant increase on the demand of electricity.
In 2005, the estimated cooling saturation in Europe was 27% for the Commercial sector and 5% for the residential sector. Nowadays the situation is very different from country to country. The residential sector, for instance, in some European countries is an undeveloped field with saturation percentages close to 1 % while in the same country the commercial sector has a completely different percentage burden.
The European Market, compared to the Asian and American Markets, has a very high room for improvement.
There are two main driving forces influencing the sales: warm climate and economic trend. The economic trend has a stronger impact than the climate conditions, however very hot summers can generate an increase in sales of air conditioning systems, for instance in 2011 the Russian market is a proof of that.
In Europe the economic situation, especially in Southern European countries, which are also the warmest ones, is quite difficult. The growth on sales was not in the latest years as expected and predicted by several studies, the financial crisis influenced deeply the air conditioning market.
It is very hard to predict the evolution of the cooling demand, and to do that, shown below are illustrated some European studies that have tried to make a prognosis on the evolution of the cooling demand in Europe.

6.2.1 A Cooling Market Estimation, RHC

The European Technology Platform on Renewable Heating and Cooling (RHC) /REF 5/ has published in 2011 a vision on the European cooling market "2020 – 2030 – 2050 Common Vision for the Renewable Heating & Cooling Sector in Europe".
The evolution of energy consumption for cooling is expected to follow a markedly different trend to that of heating: an increase of demand can be expected rather than a decrease. Climate change and a growing feeling among people will be the drivers for the growth in the cooling market.
An upper limit on the size of the market in Europe, if 100% of all useful space were air-conditioned, is estimated to be 1400 TWh per year.
Governments have been slow to spot the trend of increased cooling demand, but the policies will have to bring the technologies to supply this active cooling as green as possible, the F-Gas Regulation is a good example of that.

This prognosis hypothesize a very strong increase of the cooling demand in the residential sector from 2006-2007 until 2020 of about 82%. After 2020, conforming to RHC, the saturation of the cooling market would be high and the growth would be very limited, but this analysis considers the energy consumption as an index, and it does not consider, the possible impact of low energy consumption cooling applications as substitutes of the old ones. It means, according to RHC, from the last ten years to the next five years, the cooling demand will be very high, but after 2020, it could have a different impact, as opposed to this analysis, of lower energy consumption cooling applications.

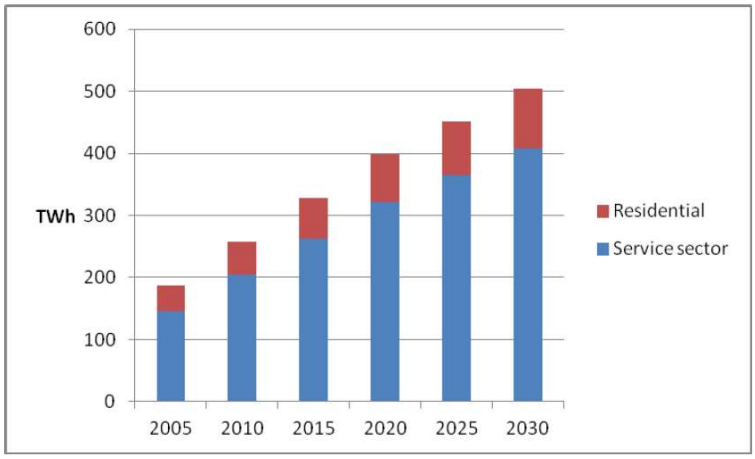


Vision on European cooling market in TWh (Source: The European Technology Platform on Renewable Heating and Cooling)

Figure 6.1: Cooling market estimation - RHC

6.2.2 A new estimation, Rescue Estimation

Rescue (Renewable Smart Cooling for Urban Europe) has analyzed the cooling market, studying the installation stock of AC equipment, a report from the project ECODESIGN, plus Market estimations of future sales of AC equipment.



Rescue cooling market estimation in the EU27 countries

Figure 6.2: Cooling market estimation - RESCUE

They have transferred all these information into an estimation of the development of cooling market saturation in EU27.
The total Cooling Market, expressed in yearly energy consumption, is estimated to be 1220 TWh per year.
In the following Table, it is possible to see the cooling market expansion in the EU27 countries corresponds to the following cooling supply saturation.

%	2010	2015	2020	2025	2030
Service sector	40	51	63	71	80
Residential	7	9	11	12	13

Table x: Cooling Market Estimation – source Rescue WP2

The saturation of cooling in EU27 for the service sector has now passed 40 % and is around 7 % for residential buildings. The EU27 cooling market saturation is estimated to grow up to the same level as in the USA, with approximately 80 % in 2030. However, the market saturation of cooling for residential is estimated to be substantially lower than in the USA's market, only 13 % in 2030.

6.2.3 The European Commission, SETIS

EU cooling demand in 2010 amounted to 220 TWh (8% of the space heating demand). According to projections contained in the Ecodesign Impact Accounting report published in May 2010, EU Space Cooling demand is expected to rise to 305 TWh (+38%) in 2020 and 379 TWh in 2030.

6.2.4 Considerations

The three studies predict very different projections, and by the way, the first one is slightly far from the real situation. As introduced in the previous paragraph data regarding the number of sold units in the last six years do not confirm the RHC's estimation (a very fast growth of the cooling demand until 2020).
The SETIS estimation and the Rescue estimation, in my opinion, are the ones that better approximate the evolution of the cooling demand in Europe at least in the short term. However they predict different long term values of energy consumption for cooling and at this point it is not possible to say how would be the situation in 2030.
According to the European studies used for these predictions most of them assume the total yearly energy consumption for cooling in Europe to around 1300 TWh per year.

6.3 MARKET TRENDS IN EUROPE

6.3.1 Overview

It should be noted that, the European is considered to be a market with great potential, with high room for improvement, compared to the American and the Japanese ones which are almost completely saturated, however a high percentage of installed cooling capacity does not entail a reduction on sales.

Regarding the cooling demand, it is certainly destined to increase during the next 15 years, however the rate of increase of installed cooling capacity is declining.

The European region declined in value in 2014 to an estimated US$ 11.2 Billion a drop by 5 % over 2013. UK and Germany were improving markets while the Italian, Russian, Turkish and Spanish ones were declining ones.

The overall German AC market grew by 2 % reaching US$ 1.2 Billion. The biggest growth was seen in UK, reaching US$ 1.2 Billion, a rise of 22 %, this is linked to commercial construction trends and mainly in the London area, especially for central plants and VRFs.

Spain, Italy, Greece, the biggest European air conditioning markets in the first decade of 21st century, continue to face a very difficult situation. The lengthening economic regression led to a reduction on investments and to a shrink on the air conditioning demand compared to the period before the crisis.

For instance, the construction market was hit by a deep crisis and it has consequences on the air conditioning market.

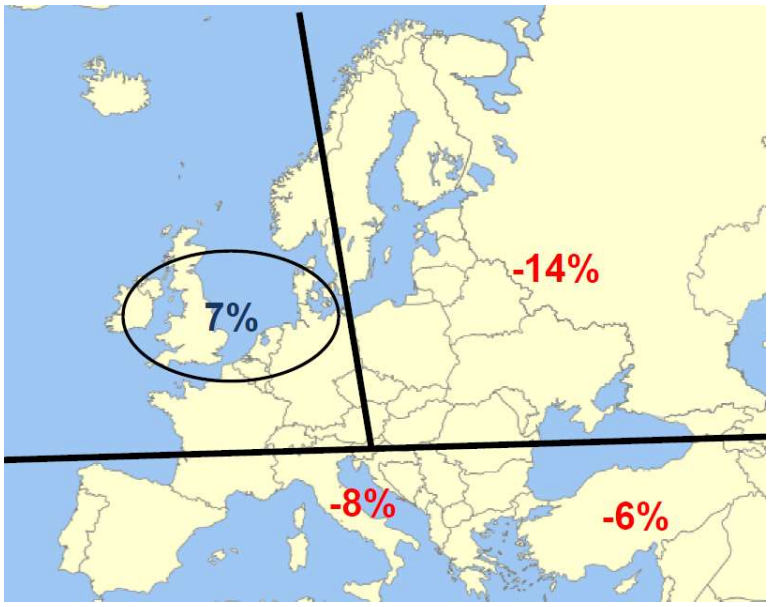


Figure 6.3: AC growth rate in Europe, source BSRIA 2014

Europe is a particular case and there are different countries with different climatic, economic and market conditions and for each of them there are several aspects that have to be considered to have a complete overview of the situation, starting from the economic situation and the construction market of the different countries among Europe. There are many dissimilarities between the different States, the aim is to identify the main differences affecting the various markets.

As previously mentioned, before considering the situation state by state, will be reported data regarding the whole European market, in which are considered the Italian, German, UK, French, Greek, Spanish, Turkish and Russian markets.

In the first graph shown above for two different periods, 2003-2005 and 2010-2013, is displayed, in terms of number of sold units, the evolution of the market.

It shows a tendency in the three years before the 2009 crisis of market growth and a decrease of the market in the period after 2009, except for 2011 (for which will be done specific considerations when the Russian case will be analyzed), in fact in the two years 2010-2011 have been observed exceptionally high temperatures in Russia, which resulted in an increase on the sales, this fact influenced strongly the market.

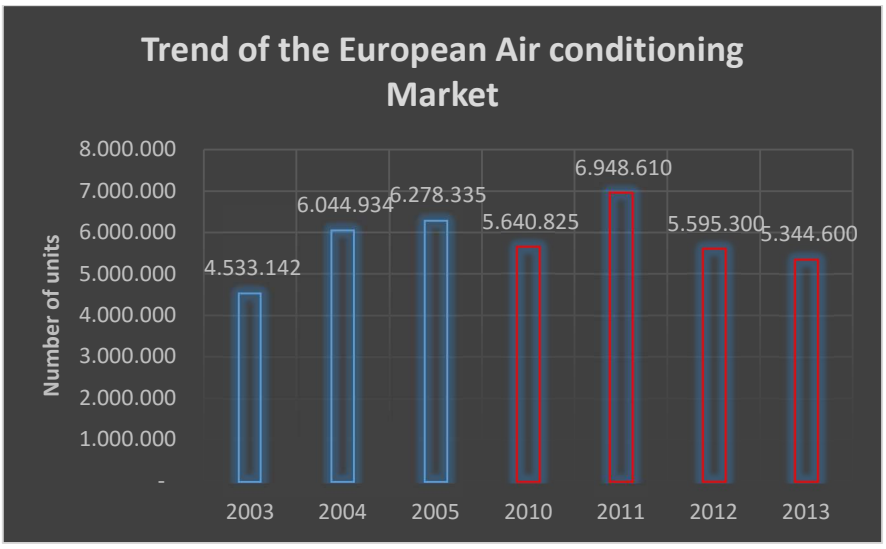


Figure 6.4: Trend of the European Air Conditioning Market, 2003-2005 and 2010-2013

This exceptional situation in Russia has maintained sales values in Europe consistent with values of about ten years before, however this hides what is the real situation in the other European countries, in particular those who, in the three years 2003-2005, represented the largest markets which in fact have suffered a huge reduction in sales. For instance countries as Italy or Spain, the biggest markets in 2004, have seen a sharp decline of their market share, whereas Turkey and Russia on the other hand have grown their total market share. As it is possible to see in the next figure in which were taken as reference year 2004 and year 2012.

Greece and France have also reduced their percentage while Germany and UK have retained almost unchanged their market shares.

This situation is due to the difficulty of recovery, especially for Southern European countries, from the economic crisis.

It is important to notice that, this figure is not showing the total number of sold units, but there is almost no difference in the number of sold units in the two years, around 6 million of units. This emphasize even more the increase and the reduction of the sales in the various markets.

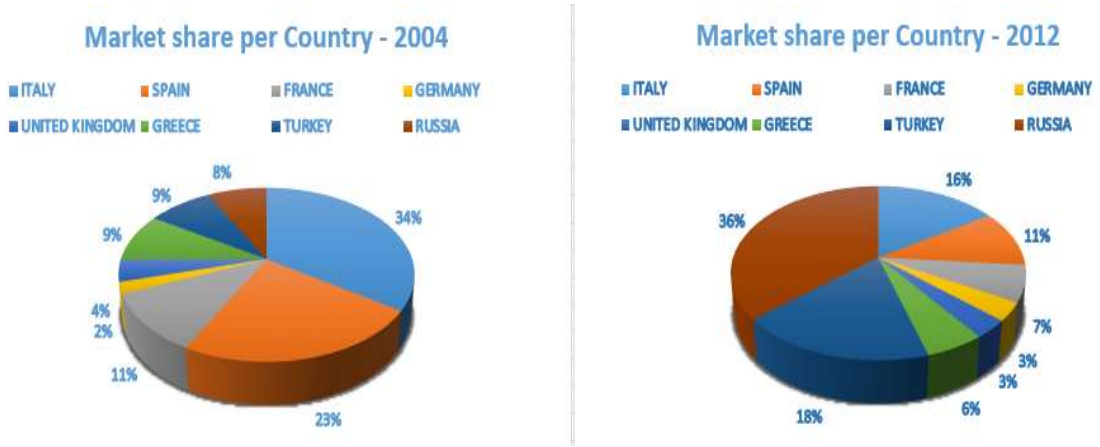


Figure 6.5: European Market shares 2004 and 2012

6.3.2 Sales by product typology

Considering the total market for the two years taken as a reference, it is appropriate to show which technologies possess the market and how they have grew or decreased their market shares. The following chart shows just that. The first thing it is possible to notice is that the "Splits" completely dominate the market since 2004 with about 90 % of the total in term of number of sold units.

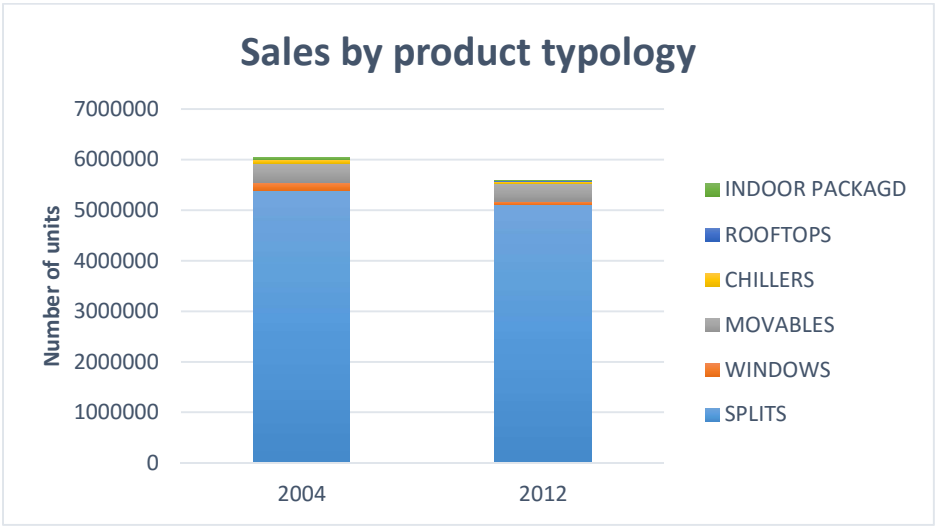


Figure 6.6: Total sales by product typology for 2004 and 2012

In the category "Splits" are considered single-splits, multi-splits, VRFs and ducted-splits. Unfortunately it was not possible in this case to divide the data for splits in the different categories and be more specific due to the lack of data, but for some singular countries it was possible and later a deeper analysis will be done.

Splits, in percentage terms in reference to the year, between 2004 and 2012 have increased their market share at the expense of movables and windows. Other technologies have approximately maintained similar values in the considered period.

Mini-splits

Splits represent the leading technology. Single-split version is the most widespread in the residential sector, especially in multifamily houses. The majority of splits sold in term of numbers are in single and multi-split versions, it depends on the country.

The figure below shows, in terms of number of outdoor units, the situation in the top 10 countries with a total of 6.5 million of units.

A lower share (in term of numbers) can be attributed to VRFs and ducted-splits which have, technologically speaking, more impact in the tertiary sector or in single-family houses, moreover their cost is also higher.

There are no innovative new technologies that during the considered period have had a remarkable effect on the market on the contrary products already present have strengthen their hegemony.

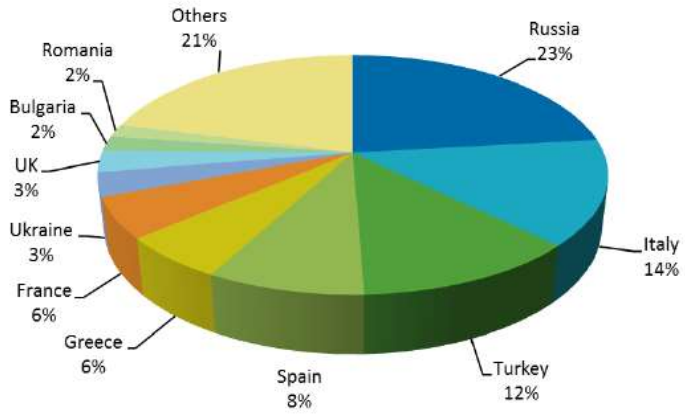


Figure 6.7: Global mini-split market – 2014, source BSRIA – Global trends in Air Conditioning

Furthermore, there are some considerations to do about splits and the impact that VRFs have had in the last years. A diagram of world sales of VRFs is shown below.

VRFs

According to BSRIA, VRF systems have gradually come to be recognized within the European air conditioner industry as superior to chiller systems at individualized control, centralized control, energy efficiency, comfort, noise level. In 2011, while European economy faced a continuing recession, demand for replacements was a big driver for the VRF technology.

It is very interesting to underline the fact that according to BSRIA, VRFs will increase the volume of sold units constantly all over the world and also in Europe.

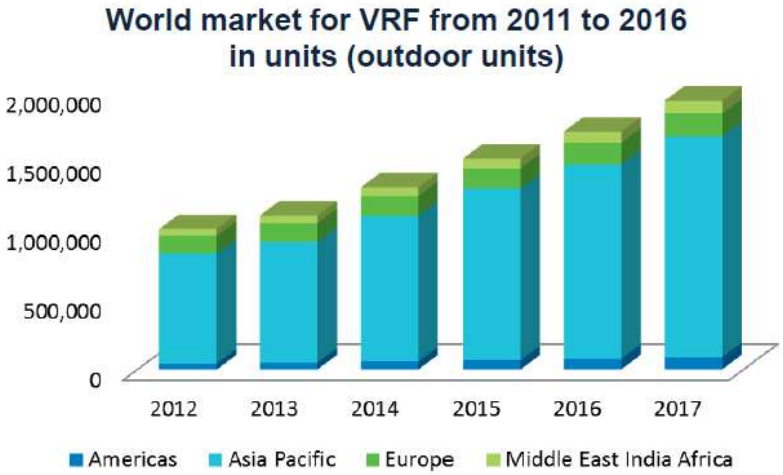


Figure 6.8: World market for VRF in terms of number of units – source BSRIA, Global trends in Air Conditioning

Countries as Germany, France and UK have a relatively low penetration of air conditioning in the domestic sector, if we compare the results regarding the percentage of VRF installations in Europe in 2014 with those of the 2012 total AC market share, in this case the percentage of VRF installations for Germany, UK and France is quite high, while for Russia, Italy and Spain is the opposite.

VRF sales in many countries are expanding, the world market size for electrically driven VRF systems is estimated to have grown almost 30 % in 2012 over 2011.

Additional data that confirms the good trend for VRFs is from BSRIA which has analyzed the European VRF market size and estimated at around 121,000 units in 2011, 8 % increase over 2010.

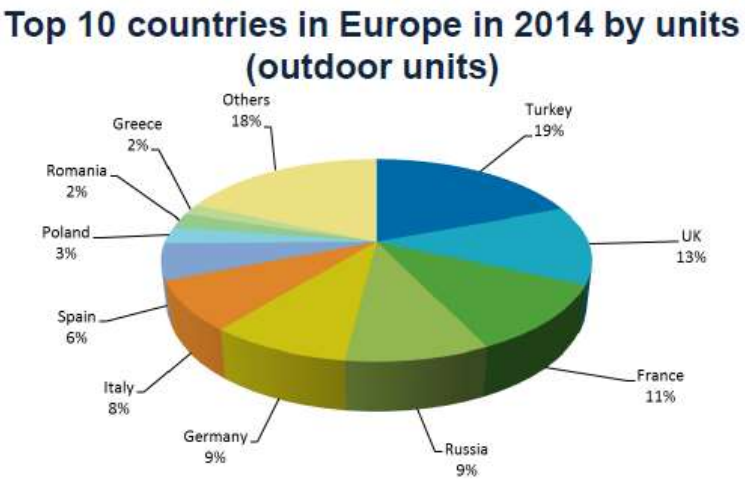


Figure 6.9: VRF market, Top 10 countries in Europe 2014 in terms of number of units – source BSRIA, Global trends in Air Conditioning

Heat pumps

Talking about Heat pumps, they are every year attracting more and more attention as energy efficiency green technology. In Europe heat pumps have been recognized as renewable energy sources and in several countries they receive incentives.

As previously mentioned when we talk about heat pumps, are considered all the categories of heat pumps except for Air/Air heat pumps. However market data provided by the EHPA includes also Air/Air units in the category heat pumps but with the main purpose of suppling heating.

It is very interesting, that the EHPA study provides data regarding Heat Pumps mainly for heating installations, it gives us other important information concerning the potential market for those systems as radiant systems or fan coil units or AHU, perfectly combinable with Air to Water, Water to Water and Ground to Water heat pumps. This may let us know how might be the impact of these systems in the market as dual function (heating and cooling) application.

In the study are considered 21 European countries, in absolute number, France is the market leader, followed by Italy and Sweden. Nearly 40 % of all heat pumps sold in Europe are sold in Italy and France. Nearly 50 % are sold in the top 3 countries and more than 86 % in the top 9.

What is interesting to notice is that the highest annual sales decrease was observed in the case of Spain with a decline of 24974 units (-33 %). On the positive side, Denmark saw a growth of 5759 units (+23.4%).

Considering the whole Europe it is not possible to have a clear overview of the market. Every country has its own tendency. More than half of the markets showed positive signs. A few of the larger markets like France, Switzerland and Germany are characterized by stable growth rates. On the other hand Spain, Italy and Netherlands showed a decline in 2012 after positive signs in 2011.

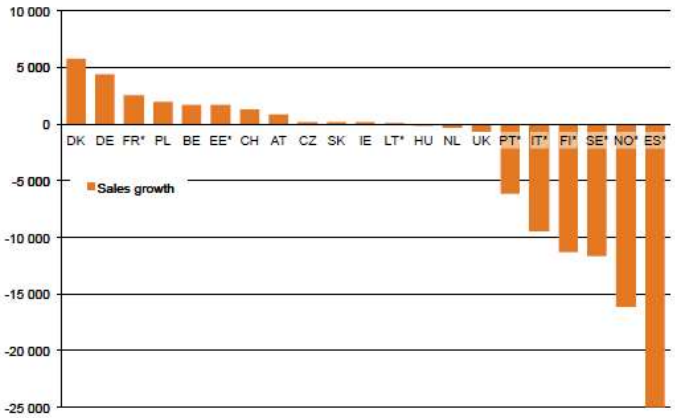


Figure 6.10: Change of heat pump sales, 2012-2013 – source EHPA Market and statistics report

Air is the main energy source with more than 85 % in the European heat pump markets. Air/Air heat pumps with heating functionality are the dominant one. While Air to Water heat pumps is a very promising technology, it is gradually gaining market traction, as a replacement for electric heaters and small boilers.

According to JARN-"World Heat Pumps Market", compared to the Air Conditioner Market, which was affected by the economic crisis, the ATW Market remained almost unchanged and shows long term growth potential.

ATW Heat pumps are generally chosen for heating operation, but most of the machines have also the possibility to work in reversible function.

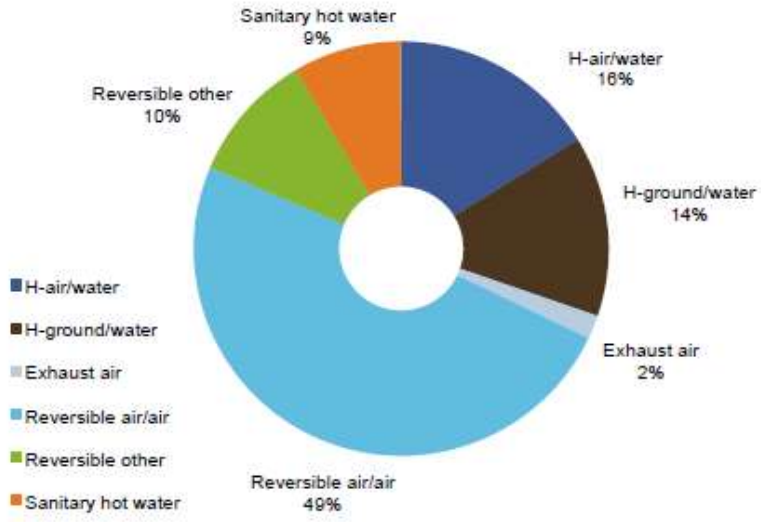


Figure 6.11: Heat Pump market by product category EU-21, 2012 – source EHPA Market and statistics report

- *Air/Air Heat Pumps*

A large number of reversible Air/Air heat pumps are installed in Europe, the choice made by EHPA was that in northern European countries their use is assumed exclusively for heating application. For southern European countries a different approach was applied, EHPA has based the study on the Italian market to determine the type of heating systems used.

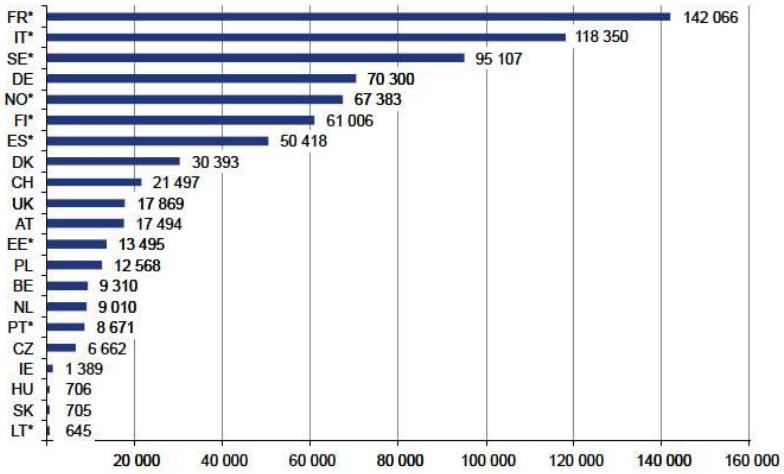


Figure 6.12: Heat pump sales numbers in 21 countries – source EHPA Market and statistics report

The study revealed that the 9.5 % of the total number of reversible heat pumps sold were installed for heating application.

The percentage was applied to the total number of reversible heat pumps sold. Sales statistics supplied additional information, 52 % of all heat pumps are sold in southern Italy and the remaining 48 % are sold in northern Italy. Based on field data, it is assumed that in northern Italy 50 % of the energy supplied to the heat pump is used for heating and the other 50 % for cooling. In southern Italy the situation is a bit different, 90 % for cooling and 10 % for heating. For France was assumed the same percentage penetration of 9.5 % of Air/Air heat pumps for heating and providing 50 % for heating as for cooling.

To other countries as Spain, France, Portugal and other coastal areas was applied the same percentage for the penetration of Air/Air heat pumps for heating.

	Northern Italy	Southern Italy	Central/ Northern Spain, Portugal	Southern Spain, Costal areas	France
Heat pumps as only heat generator	9,5 %	9,5 %	9,5 %	9,5 %	9,5 %
Share of installed units	48 %	52 %	50 %	50 %	100 %
Energy used for heating	50 %	10 %	50 %	10 %	50 %

Table 6.1: Distribution of heat pumps and contribution of heating in southern European countries – source EHPA Market and statistics report

- *ATW and Ground sourced Heat pumps*

The European ATW market is mainly centered in France, and now is showing signs of gradually growing markets in Germany, UK and Eastern Europe.

The EHPA affirms that heat pump sales in Europe (ground, water and air source HP) are over 770,000 units in 2011 showing a year-on-year growth of around 7.7 %. While in 2012 were around 750,000 units, a slight decrease. According to the EHPA, European ATW market scale was 170,000 units in 2011, 22 % of the total. Year-on-year growth of 7.7 %.

Ground-sourced heat pumps is a widely adopted solution, especially in those countries where are available big spaces. For all Europe, the ground-source heat pump market in 2011 was around 108.500 units, increased year after year by 6.8 %.

The use of the different typologies of heat pumps differs from country to country. In general, aerothermal units are used in warmer climates where they can be used also for cooling application, while countries with colder climates ask for a source characterized by a less variable temperature during the year, however there are also some examples, for instance in the Nordic countries where the penetration of Air sourced heat pumps have is quite high. Other elements as building standards, awareness of a technology or preference for a specific system influence the choice of the energy source.

The EHPA report, presented the number of heat pumps sold as a function of 10,000 households based on Eurostat data in order to understand the penetration of heat pump technology in the various countries and to evaluate market shares. Scandinavian countries have a very high penetration while a low penetration for all the others is observed. This fact indicates that almost all markets in Europe have a large growth potential, especially in the large markets of Italy, Spain, Germany and France.

- *Heat Pumps – Market segmentation*

According to the EHPA Market statistics, considering the total HVAC market the heat pump sub-market is increasing importance while the heating, air conditioning and ventilation markets are stagnating ones.
It is possible to differentiate the total market into segments: new buildings or existing ones and residential or non-residential buildings.

- *New residential single-family houses*: it is the best developed segment with a very high penetration in countries as Sweden and Switzerland with a 95 % and 80 % penetration respectively. Developing markets as Austria, Finland, France, Germany and Norway heat pumps have reached a penetration of around 25 %.
- *Renovation for single family houses*: it is a very interesting application and it is considered to be the most promising one in the long term. In Sweden and Switzerland the market share is around 10 % while in developing markets as Austria, France and Germany the shares are under 10 %. Temperatures reached in winter operation are increasing (up to 65 °C) for the purpose of replacing existing boilers.
- *Residential multi-family houses*: this segment is developing slowly.
- *Non-residential buildings*: it is gaining more and more importance, large buildings have a demand for heating and cooling and heat pumps is the perfect technology.

This general trend is driven by adoption of heat pump technology in the segment of new single-family houses followed by the segment of renovation also in single-family houses. It is easy to integrate the heat pump technology into the planning of a new building and single-family dwellings are also more suitable for this kind of technology from an economic point of view.

7. REPORTS ON SELECTED EUROPEAN COUNTRIES

7.1 INTRODUCTION

After having analyzed the European market as a whole, we have noticed that the situation among the various European states is very different and it is not possible to make a prediction on the trend considering the total European market. As previously mentioned the only way to have a deep comprehension of the whole market is to analyze data for each country, also because the economic situation is very different and especially southern European countries are facing a bad situation.

The purpose of this chapter is to observe the situation state by state, the evolution of the different Air Conditioning and Heat Pump Markets in order to have an overview of the technologies which have had a greater impact on the market and their market share evolution from 2003 to 2012.

For countries as Italy, Spain, France, Germany, Greece, UK, Turkey and Russia data from BSRIA and JARN newspapers were available, while for Northern European countries as Sweden, Denmark, Norway and Finland reference has been made to the EHPA market and statistic report.

Moreover, to make a prediction on the potential market for radiant systems, data regarding underfloor radiant systems for heating application was taken in consideration. It can give us a viewpoint on the potential market for this technology for cooling application.

In addition to this, data related to the trend of the construction market for each single country were also analyzed.

7.2 ITALY

7.2.1 Introduction

The economic crisis blew from the United States in 2008 carried a very hard economic situation in the immediately following years in all southern European countries, especially Italy, Greece, Spain and Portugal. From 2009 onwards all these countries suffered the worst economic crisis since Second World War.

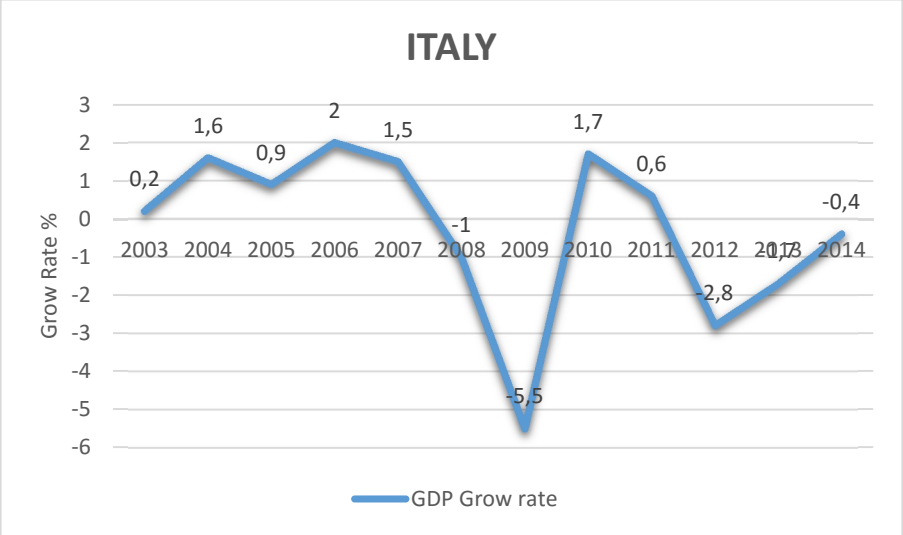


Figure 7.1: GDP Grow Rate in percentage, Italy – source EUROSTAT

Looking at Eurostat data, in 2012 Italy saw a decrease on GDP of around -2.8 %, a fall of -1.7 % was observed in 2013 and in 2014 followed a GDP fall of -0.4 %. The prospects are quite difficult to predict, however the trend shows a slight recovery but the percentage still is negative.

Italy suffered this situation and the economic recovery seems to be very distant.

The Italian climate is generally Mediterranean, but with significant differences among different regions. The North-East of the country is characterized by a continental climate with very hot summers and cold winters, the Central and the Southern regions and also included the islands are characterized by very hot and humid summers.

Natural gas is the dominant energy source in the residential sector, and space heating has the largest share of household energy use, corresponding to an average of 65 % of the total energy consumption. Water heating accounts 10 % while air conditioning still represents a marginal share of residential consumption.

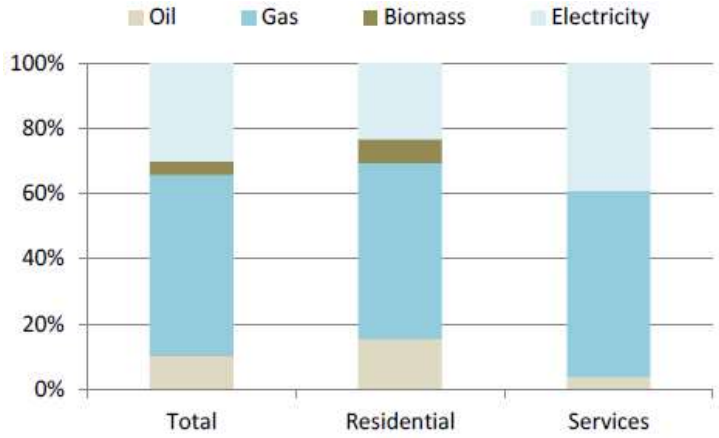


Figure 7.2: Total energy consumption of the building sector (2008) - source ENTRANZE Project, IEE

According to the 2013 JARN report on the Air Conditioner Market, in 2012 the penetration of air conditioning reached 44 % in the commercial sector and 21 % in the residential one.

Information available produce data only for the periods 2003-2005 and 2010-2013, however in the JARN newspaper "World Air Conditioner Market 2012"is available a graph where is plotted the evolution of the split market in Italy exactly in the crisis period.

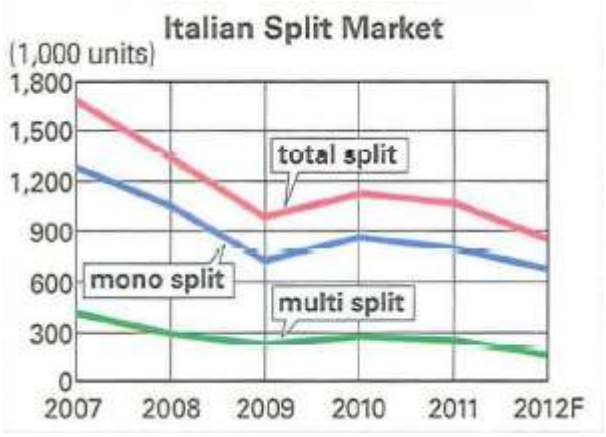


Figure 7.3: Italian Split Market – source JARN, World Air Conditioner Market 2012

If we compare the two diagrams what is very interesting to see is that the air conditioning market is strongly influenced by the economic situation, it follows the trend of the GDP Grow rate.

7.2.2 The Italian Air Conditioning Market

The Air Conditioning Market was deeply affected by the economic crisis, Italy represented in 2004 the biggest European market with around 2,160,000 units sold a 34 % market share as previously showed, in 2012 the market has more than halved accounting 913,000 units sold in the year, Italy now accounts 16 % of the European Market. Sales performance of splits perfectly approximates the evolution of the market. Splits accounted and accounts a share from 80-90 % of the total market since 2003.

In 2004 the Italian market for air conditioning was one of strongest, the largest for mini-splits with over 1,5 million of units sold, it was characterized by a very high growth in the years immediately preceding the economic crisis.

In the residential sector, especially in the north of the country, several buildings were equipped with an air conditioning system.

According to BSRIA 2005 report, the concentration in the distribution channels were in 2004 developing very fast, this is another reason why split systems are very widespread nowadays.

The majority of indoor packaged units were in 2004 almost all of them small units, with less than 7 kW of power, most of them for small commercial applications.

The Italian chiller market was the largest in Europe, however in 2004 the competition was increasing from VRF products.

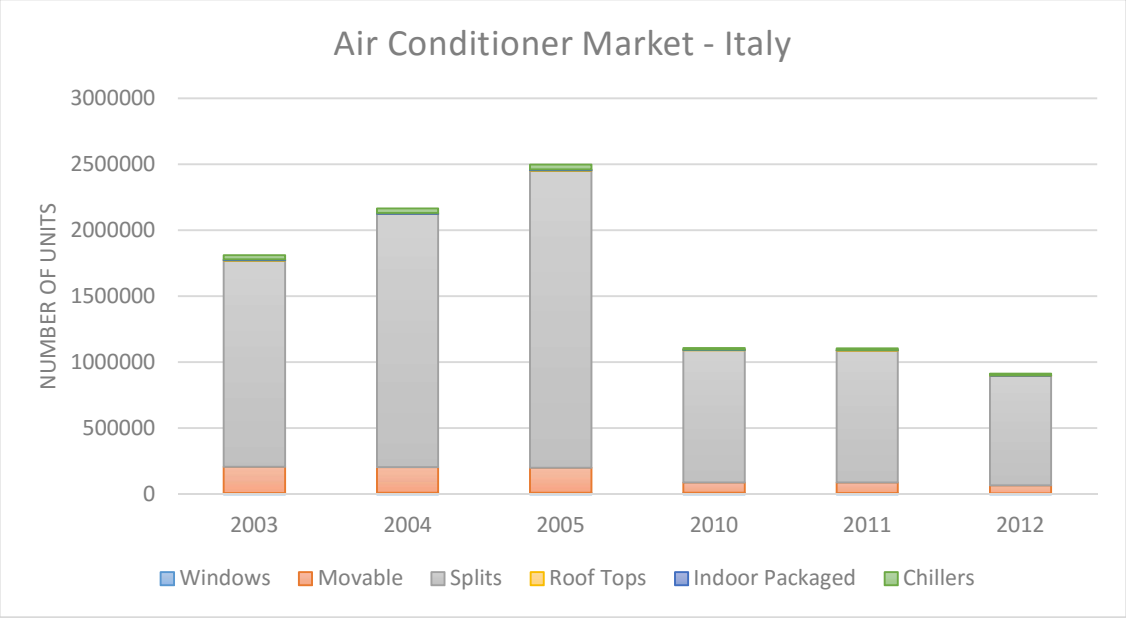


Figure 7.4: Italian Air conditioner Market – source BSRIA 2005, JARN 2012-2013

Sales for Windows in 2010 were 10,500 units, 9,300 units in 2011, reaching 7,300 units in 2012, and their market is exclusively a replacement market. The perspective is a continue reduction. In the next future split units will substitute this technology.

Movables accounted around 79,000 units in the two years 2010-2011 while even the hot summer in 2012 with summer average temperatures of 26 °C sales fell to 60,000 units. The sales suffered a very hard contraction in the last 15 years, around 190,000 units were sold in 2004.

The Italian Market for mini-splits was the largest in Europe in 2004 with more than 1.5 million of units sold.

Splits (single, multi, VRF and ducted) accounted around 1,900,000 units while in the two years 2010-2011 fell to just over 1,000,000 units, 830,000 units were accounted in 2012 and in 2013 were expected 725,000 units sold. The prediction is confirmed by the statistic report from COAER-ANIMA, "Un anno di luci e ombre nel mercato della climatizzazione". Also for the split case the trend is for a decline in sales but in value terms the market for single- and multi-splits is growing.

Single-split units in the range of 3.5-5 kW was in 2004 the most popular ones, mainly in the residential sector.

Single-splits account for three quarters of the market in term of numbers. Whereas Italy still remaining the biggest market for multi-splits in Europe.

VRFs reached a value of US$ 192 million in 2012 compared with a total market of US$ 894 million. In 2011 the market reached 16,000 units, a slight increase from 2010. In 2012 decreased by 11 % compared with 2011, reaching 14,300 units.

85% of chillers sold in Italy were below 100 kW accounting around 30,000 units, while in 2011 Chillers sold were 12,500 units with power under 100 kW.

AHU sales were 21,000 units in 2011 and it is a stable market.

Italy represents the biggest European market for FCUs[3], over 400,000 units sold in 2011 at a value around US$ 130 million.

Regarding radiant cooling systems, it is not available significant market data, however a study from the Q-Rad association on radiant systems affirms that in the residential sector especially for renovations, radiant technology is a growing trend in the last few years.

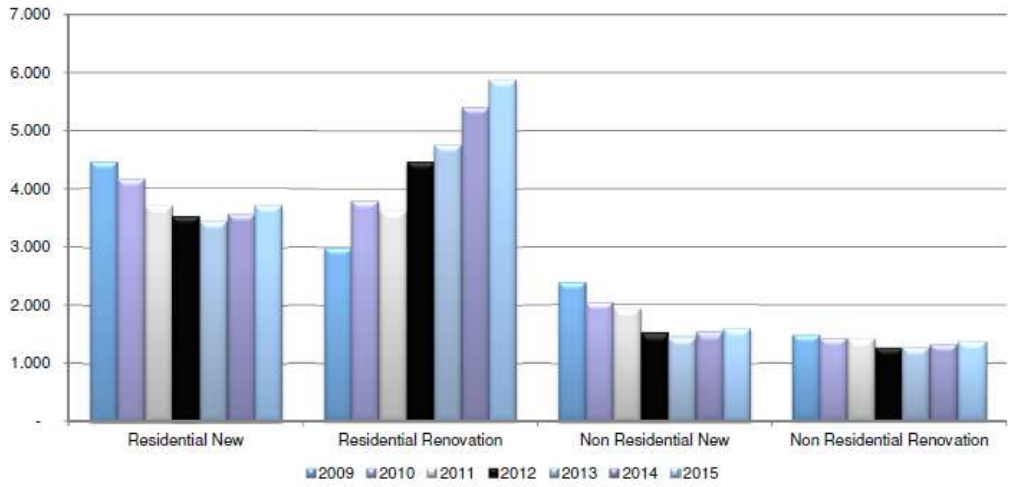


Figure 7.5: Valuation thousands of square meters covered with radiant systems per building type – source Q-Rad Association

Especially in the renovation sector, where in the last years the growing trend is remarkable.

a) b)

[3] AHUs (Air Handling Units), FCUs (Fan Coil Units)

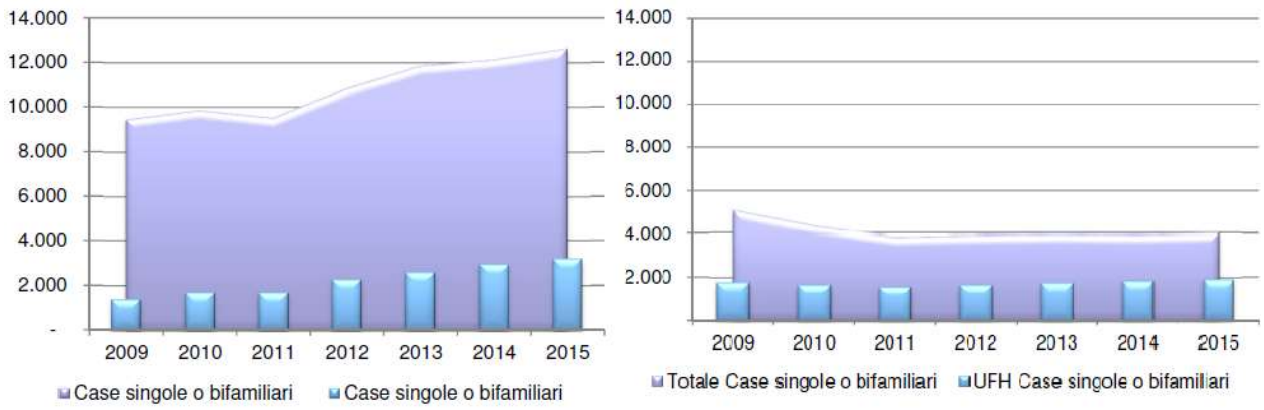


Figure 7.6: a) Valuation thousands of square meters for single-family houses, renovation sector b) Valuation thousands of square meters for new single-family houses – source Q-Rad

If we consider only single-family houses, the trend is more or less the same. Radiant technology is more and more widespread in the residential sector and it is chosen mainly for heating applications.
It is very difficult for radiant cooling systems to reach a significant market share in the cooling market, however the continued spread could change future perspectives, dual function radiant systems (heating and cooling) could substitute heating only ones and it could be the solution for radiant technology to cover that market share.

7.2.3 The Italian Heat Pump market

The market for Heat Pumps has been representing a quite interesting market in the latest years, even during the years after the economic crisis was an increasing market, however it has fallen by a 7,4 % in 2012. As it is possible to observe from the following figure.

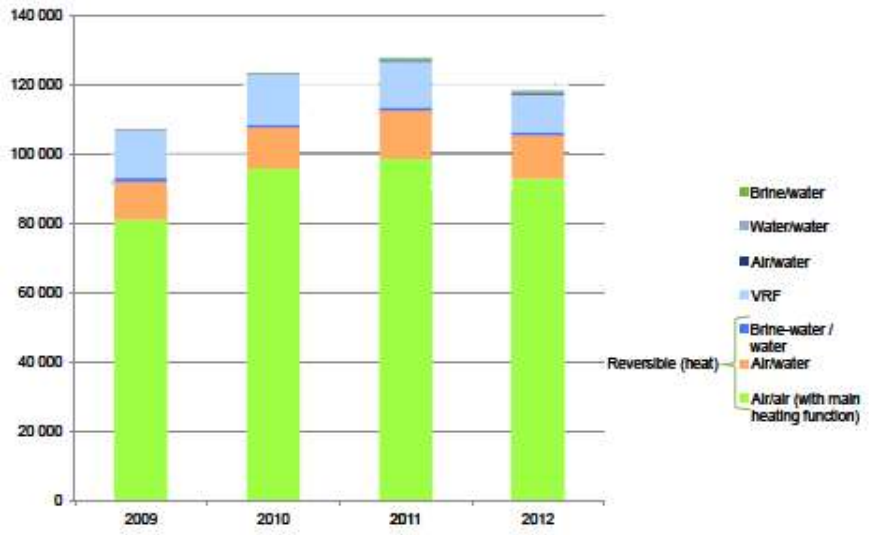


Figure 7.7: Italian Heat Pump market, 2009-2012 (number of units) - source EHPA Market and statistics report

In the residential and also in the non-residential heating sector the “heating only” units installed suffered a decrease of around 34 % while reversible heat pumps used for both cooling and heating applications fell by only 8 %.

Air/Air reversible heat pumps continue to have a bigger market share in the Southern region, where climate conditions are more favorable. Anyhow latest campaigns for the use of heat pumps as primary source for heating is producing good results also in the Northern region where air/water ones are also producing very good results in latest years.

MARKET TRENDS HEAT PUMP TECHNOLOGY

Heat Pump type	2010	2011	2012	2011/2012 evolution
Air/Water	150	379	350	-7.70%
Water/Water	179	424	408	-3.80%
Brine/Water	178	409	408	-0.20%
Reversible(total heat)	122,825	126,527	117,103	-7.50%
District heating	44	80	91	13.80%
Total	123,376	127,819	118,360	-7.40%

Table 7.1: Market trends for heat pump type - source EHPA Market and statistics report

From the scheme above it is interesting to notice that Reversible heat pumps (where are included Air/Air with main heating function, Air/Water and Brine-Water/Water) represent almost the entirety of the market.
Some industry organizations are discussing with the Italian Energy Authority in order to reduce electric tariffs and improve the use of heat pumps for primary heating and as consequence cooling.
In Italy as in other country the greatest limitation for a diffusion of this technology is the price for electricity compared to the price of other energies, for instance Natural Gas. The difference between the two prices is still too high and it is still not convenient the use of electric driven heat pump instead of a Gas driven boiler or a heater. The possible introduction of incentives or a possible reduction on electricity price for the use of heat pumps can change the perspectives.
Until June 2013 there were incentives for replacing winter heating systems with high efficiency heat pumps. The form of the incentive was a deduction of 55 % from the taxes IRPEF and IRES.
Another important driver that can change the situation in the next future is also the diffusion of photovoltaic systems in the residential sector and also in this case incentives are very important.
Furthermore reversible models will in the next future cover the totality of the market, therefore dual function systems heating and cooling would be the perfect solution. As previously described, reversible Air/Air heat pumps are gaining popularity even for the heating application, especially in Southern Italy, where there are favorable climate conditions, this technology could be the main one in the next future.

7.2.4 Italian Residential Construction Market

According to the Entranze project, the total building area in Italy is around 3,000 million of m^2, 86 % are residential dwellings and the rest service buildings.
26 % of the residential stock is composed by single-family dwellings with an average size of 110 m^2.

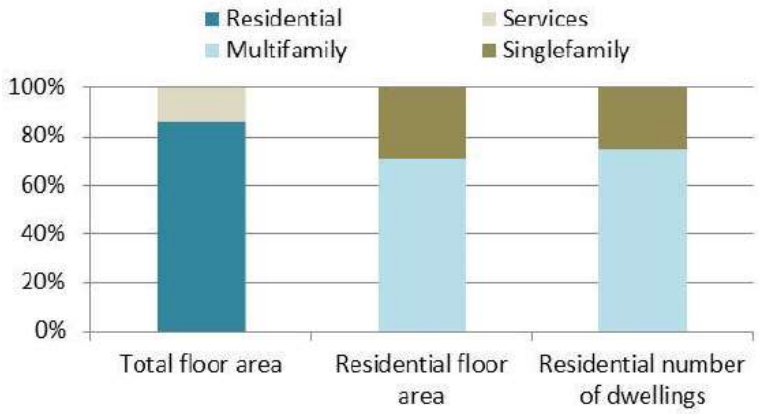


Figure 7.8: Decomposition of buildings by type (2008) – source ENTRANZE Project, IEE

The average age of buildings and the share of new buildings in the total stock give us information on the quality and the standards of constructions.

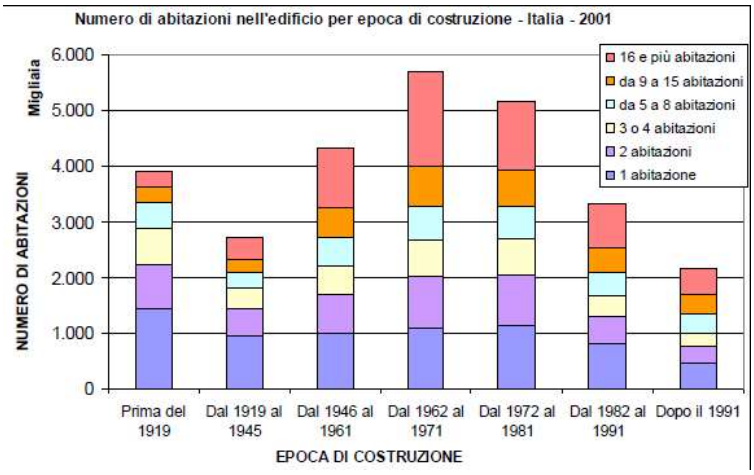


Figure 7.9: Number of household per building by period of construction, source TABULA, Episcope project

According to the TABULA project, most of them has been constructed in the period between the 60s and the 80s as it is possible to observe from the figure above.

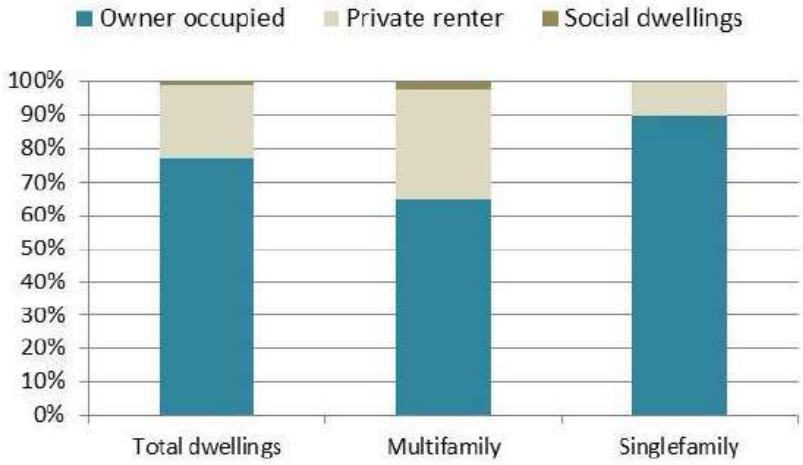


Figure 7.10: Breakdown of ownership & tenure (2008) – source ENTRANZE Project, IEE

About 72 % of the dwelling stock existing in 2008 was built after 1976.

In buildings occupied by residents, owner occupants are dominant: 77 % of total stock and 90 % in single-family houses.

The Italian construction industry has been in downfall since 2008.

The residential construction sector was the largest market accounting 59.4 % share in terms of value in 2013 and 55.8 % in 2014.

According to CIC the Italian construction market is expected to recover in the next four years, new investments are prospected. It will bring the sector on a slight upswing, the main drivers will be the country's rising population and urbanization and positive developments in regional and global economic conditions. The market is expected to perform a CAGR of 1.17 % over the forecast period (2014-2019) and value in 2019 EUR 125.1 billion.

Regarding the residential sector, its evolution on the last five years and a broadcast is displayed in the following figure, in terms of value.

Figure 7.11: Italian Residential Construction Output by Product Type – source Construction-IC

Single-family houses account in term of value almost half of the total market. However during the last decade the share of multi-family dwellings in annual construction became very important, representing 91 % of new realizations.

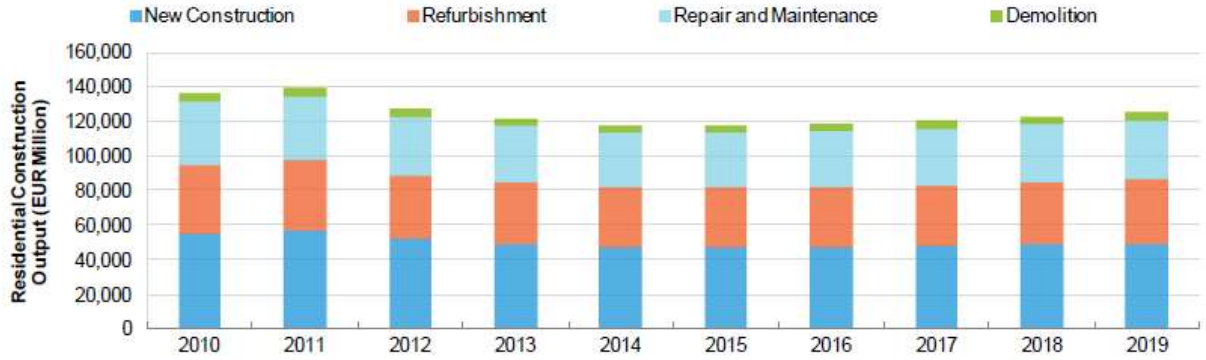


Figure 7.12: Italian Residential Construction Output by Activity Type – source Construction-IC

Furthermore, in Figure 7.12 is showed in value terms the Italian residential market by activity and it is possible to notice that around 40% of the total market will be oriented on new constructions, in 2019 is expected to reach a

value of EUR 47,353.8 million, while the rest of it in refurbishments and maintenance while the demolition activity counts a small share.

7.2.5 Considerations

Italy is characterized by a very warm climate, and the conditions for a significant spread of air conditioning systems are very favorable. However, the Air conditioning market in Italy is strongly influenced by the economic situation, the financial crisis has been deeply affecting the cooling market and the recovery seems to be very remote. In the past the Italian air conditioning market has been the biggest in Europe.

The penetration of air conditioning in the residential market is far away from saturation, according to JARN the percentage is around 21 %, and the reduction of market share cannot be attributed to a high penetration of the Air Conditioning.

In southern Italy reversible Air/Air heat pumps could also become a very interesting solution even for heating applications. Other typologies of heat pumps, those who can be matched with radiant systems for instance, to be more competitive, need incentives.

Regarding the construction market, most of the buildings have been built in the past and the building sector is facing a bad period however a recovery is expected in the next years but still the residential construction market in Italy is quite saturated. Cooling systems which can be installed easily are preferred.

Southern Italy is characterized by a very warm climate and the need for heating is quite low. The heating demand could be satisfied by Air/Air heat pumps as mentioned in the EHPA report and split units could also play a quite important role in the heating application.

7.3 GERMANY

7.3.1 Introduction

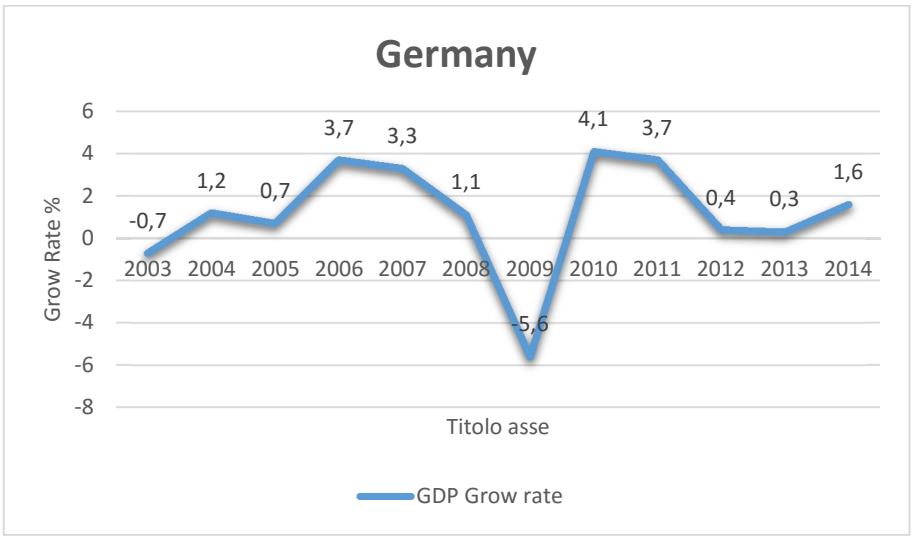


Figure 7.13: GDP Grow Rate in percentage, Germany – source EUROSTAT

Germany is Europe's strongest economy, faced the economic recession better than all the other European countries. German GDP, after a period in the first years of the 21st century of flat economy, GDP has been always on positive values except for 2009 where the situation drastically worsened where GDP dropped by more than 5 %. After that period the situation immediately improved. Nowadays perspectives are very optimistic.

The construction industry is expected to grow by an annual 3-4 % over the next few years and more detail data will be shown in the construction market paragraph.

The penetration of air conditioning in the commercial sector was around 60 % in 2012 while the residential one accounts a penetration of less than 2 %. Germany is characterized by two different climate zones. A maritime climate in the northwest and a continental climate in the South-East part. The average annual temperature is around 9 °C.

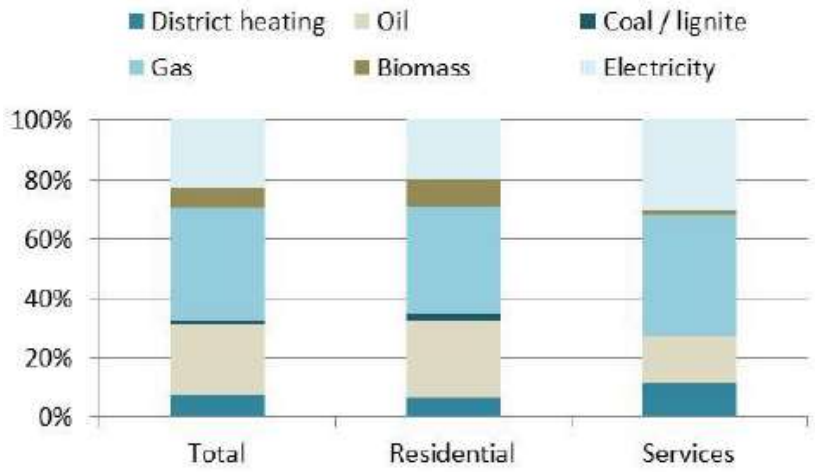


Figure 7.14: Total energy consumption of the building sector (2008) - source ENTRANZE Project, IEE

Natural gas is the dominant energy source in German buildings.

Space heating represents the largest share of household energy use, corresponding on an average to around 84 % of the total energy consumption. While water heating around 14 % and air conditioning is almost not relevant.

7.3.2 The German Air Conditioner Market

The German Air Conditioning Market in 2004 was one of the smallest in Western Europe. It was essentially a market addressed to the commercial sector. Except for the movables technology.

The German chillers market was in 2004 the largest in Europe after Italy in terms of value. Chillers up to 100 kW of power represent 60 % of the total market.

Sales for windows were in a steadily downward since 2004 due to the completion from split units and they have been falling in the latest years at an average of 19 % per year, over the last five years reaching 7,000 units in 2011 and 4,600 units in 2012 and they are destined to reduce their market share. They are mainly chosen for replacements.

Movables experienced an increase in the considered period almost doubling the number of units sold, in 2004 were around 47,000 units sold while in 2012 accounted 76,000 units sold with the prospect of continuous growth for the next few years.

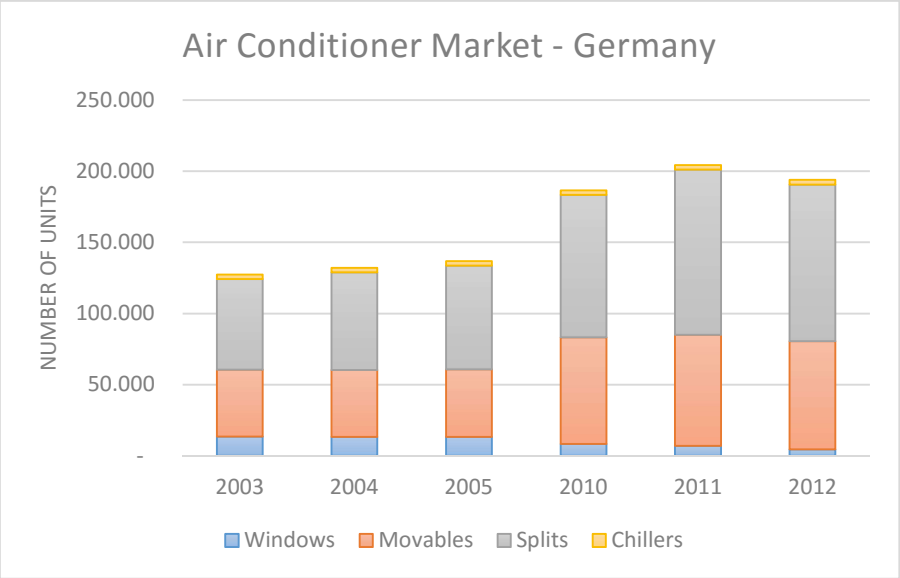


Figure 7.15: German Air conditioner Market – source BSRIA 2005, JARN 2012-2013

Splits have been supplying a relatively small market segment compared with the other European countries. It reflects the small penetration of Air Conditioning in the residential sector.

Mini-splits dominated the market in the three years 2003-2005 with over 50 % of market share. Single-splits accounted 90 % of volume share, and in term of size over half of them were below 5 kW of power in 2004.

Splits registered a sales volume of 110,000 units in 2012, a market of just over US$ 312 million of which more than 50 % in value terms are VRFs, confirming the fact that the residential sector is very far from the saturation.

Splits are viewed as a high quality, high performance products. According to JARN newspaper May 2013, this will ensure future popularity to this technology.

VRFs are installed primarily in the commercial sector and more than half of the total in new constructions. In 2012, the German market for VRFs accounted 9,800 units.

Indoor Packaged and rooftops account a very small market.

Chillers with a power under 100 kW remained a stable market, accounting in 2012 around 3,200 of units sold.

Germany was the biggest market for AHUs in 2004. In 2012 accounted 55,000 units sold, and the highest demand is for small units (<1,5m^3/s) with 26 % of the market in terms of numbers and it is considered an expanding sector.

FCUs accounted 72,000 units sold in 2010 and 76,000 units in 2011 and are expected to remain stable in the following years. Heating and cooling models are in the majority at 60 % of the sales.

Market data regarding radiant cooling systems is completely absent. However, it is available data regarding underfloor radiant heating systems, in Germany in the two years 2008-2009 were sold around 90 million of m^2 per year.

7.3.3 The German Heat Pump market

The German heat pump market has been an increasing market since the 90s reaching the highest value in 2008. The 2009 financial crisis influenced the sales and in latest years the trend is returning to be the one of the pre-crisis period. Compared to 2011 values, in 2012 the volume of space heating units grew by 4.4 % and by 20.2 % for sanitary hot water heat pumps.

If we take into account negative factors as the financial crisis and the high electricity prices in Germany, the heat pump market represents a very promising field. The reasons for this could be various and they cannot be found in political changes or other administrative conditions.

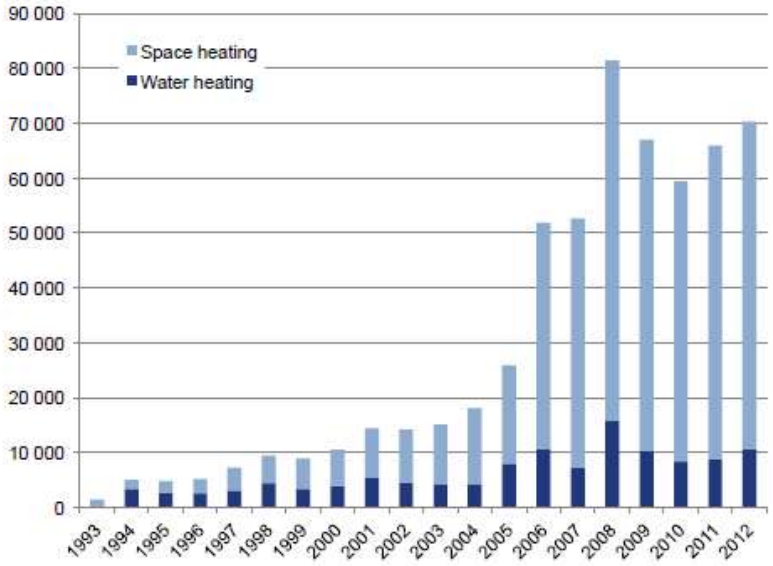


Figure 7.16: German Heat Pump Market Development 1993-2012 (number of units) – source EHPA Market and statistics report

According to the EHPA report, the reasons have to be attributed to the change in consciousness of German consumers, which are asking for more efficient and green renewable heating systems. In my opinion the high spread of small photovoltaic systems is another factor that has influenced this market.

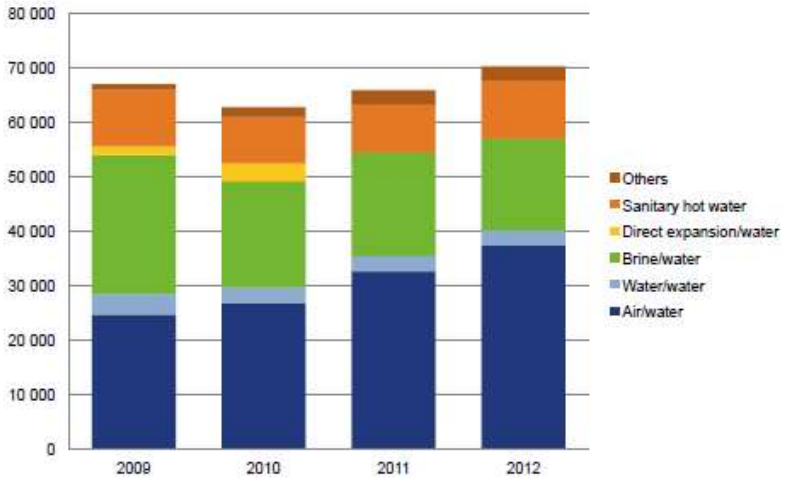


Figure 7.17: German 2009-2012 Heat Pump Market by type - source EHPA Market and statistics report

In August 2012 was introduced in Germany the Marktanreizprogram (MAP), a very important incentive program for renewable heating. The number of applications in the case of heat pumps using this incentive program decreased. A demonstration of the no significance of political interventions.

The evolution of the market has been accompanied by market share changes, for instance Air/Water heat pumps has been increasing their volume since 2009, accounting in 2012 62.7 % of the total market, an increase by 14.7 compared to 2011 value. Whereas, it should be noted also the decline by 9 % in volume of Ground Source Heat Pumps.

The sales for heat pumps are expected to increase in the coming years especially the Air/Water models which are becoming very popular in new single-family houses. Air/Air heat pumps are not frequently used in the residential.

MARKET TRENDS HEAT PUMP TECHNOLOGY

Heat Pump type	2009	2010	2011	2012	2011/2012 evolution
Air/Water	24,664	26,796	32,616	37,400	15%
Water/Water	3,782	2,834	2,758	2,800	2%
Brine/Water	25,589	19,525	19,089	16,800	-12%
Others	983	1,879	2,557	2,600	-0.71%
Sanitary Hot Water	10,406	8,401	8,853	10,700	21%
Total	65,424	59,435	65,873	70,300	7%

Table 7.2: Market trends for heat pump type 2009-2012 - source EHPA Market and statistics report

More and more buildings use heat pumps combined with photovoltaics in order to use directly the self-produced electricity. This application is becoming really popular and it could have a really big impact.

Electricity prices in Germany are the highest among Europe, and it is a very big limit for this technology.

Heat pumps which can operate in a smart grid has been introduced on the market at the beginning of 2013. The technology is ready but the high electricity prices and the inflexibility of the tariff are the biggest limits for the spread of this technology.

However the tendency is a slow change towards a revision of electricity market's policies not only in Germany but all over Europe.

A study made by the German Heat Pump Association affirmed that of two possible scenarios the more optimistic one predicts annual sales in 2030 of 300,000 units, increasing by almost six times the market, with the dominant solution Air/Water Heat Pumps with a 70 % share in 2030. In the second scenario the number of units sold in 2030 would be around 115,000 getting 20 % of the total heating generation market.

7.3.4 German Residential Construction Market

The total building area in Germany is around 4,350 million of m^2, composed of ¾ by residential dwellings. Nearly half of the total dwellings are single-family houses (46 %), the rest are multi-family ones.

Single-family dwellings are on average 50 % bigger than multi-family ones, with an average size of 110 m^2, while for multi-family dwellings is 58 m^2. The share of single-family dwellings is dominant also in the total floor area with a 60 % share.

In Germany, only 26 % of the total stock existing in 2008 was built after 1977.

The construction market decreased on average by near 9 % per year between 2000 and 2010.

Dwellings built after 2000 represents 6 % of the total stock. During first decade of 21st century the share of single-family dwellings in annual construction increased by 10 %.

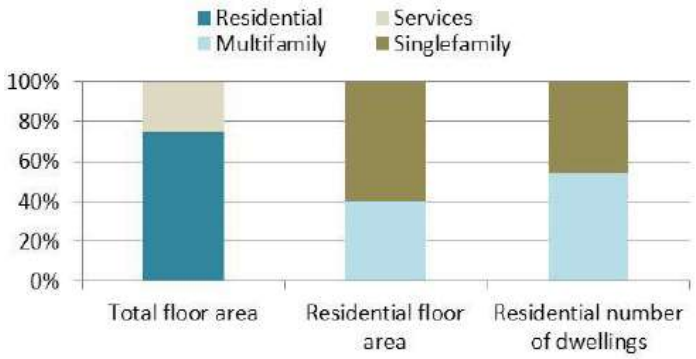


Figure 7.18: Building by type - source ENTRANZE Project, IEE

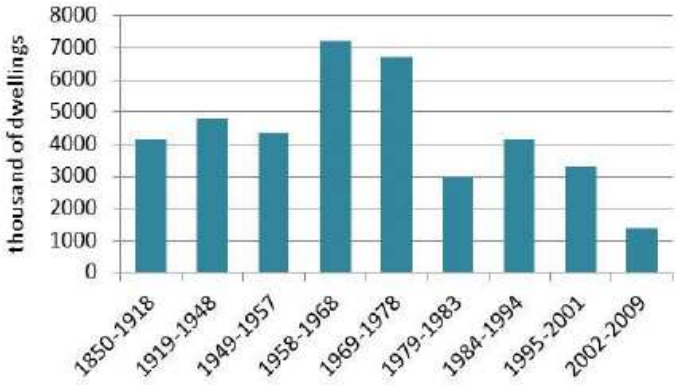


Figure 7.19: Residential dwellings according to construction date - source ENTRANZE Project, IEE

Private renters are dominant in the residential sector, 54 % of the total stock do not own their house and more than 76 % is the share in multi-family houses.

In single-family houses is the complete opposite, 83 % occupants are the owners.

Figure 7.20: Breakdown of ownership and tenure – source ENTRANZE Project, IEE

During the period 2009-2013, the German construction industry recorded a Compound Annual Growth Rate (CAGR) of 4.22 % and valued EUR 260.0 billion in 2013.

The residential construction sector accounted an industry share of 44.9 % and a value of EUR 116.8 billion was the largest market in 2013. Declining on housing interest rates, rising levels of employments and an urbanization trend supported the demand for private housing.

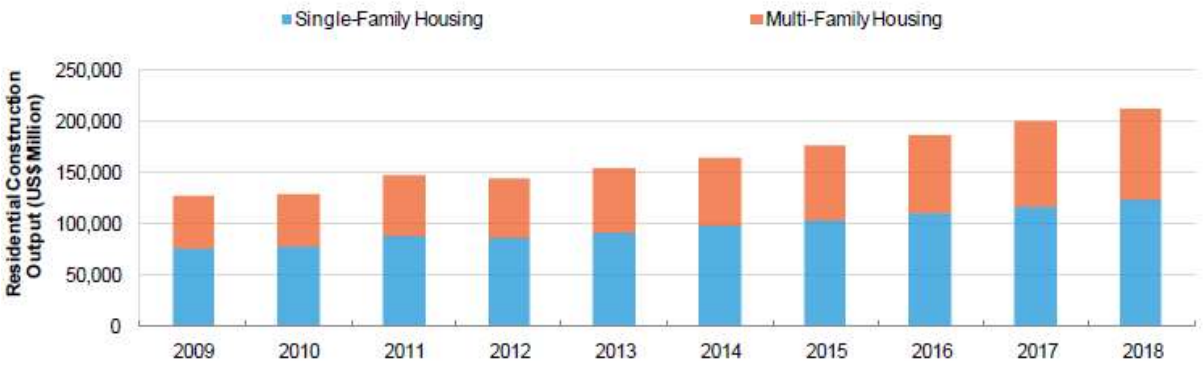


Figure 7.21: German residential Construction Output by Project Type, 2009-2018 – source Construction-IC

The market is expected to be the fastest growing over the forecast period and prospects are an increase on the CAGR of 5.35 % and to value EUR 151.5 billion in 2018.
Single-family housing category was the largest in the German residential construction market with a share of 59.3% in 2013, followed by Multi-family housing the second largest category within the residential construction market, with a 40.7 % share of the total market value in 2013.

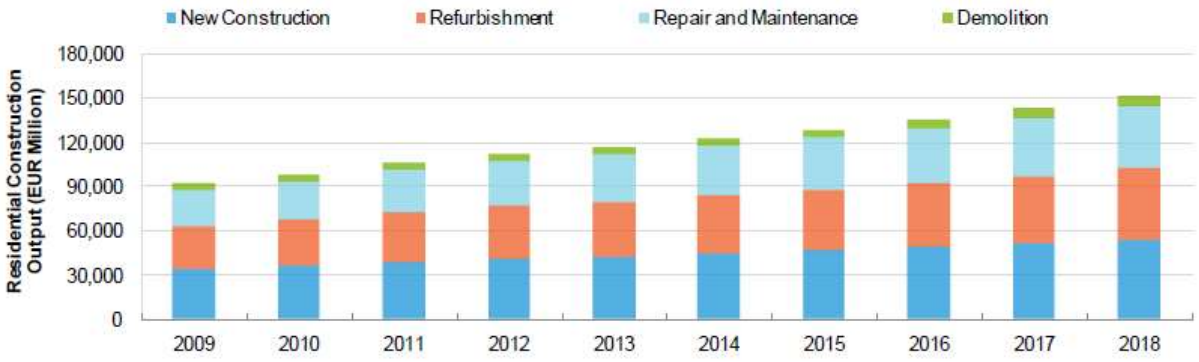


Figure 7.22: German residential Construction Output by Activity, 2009-2018 – source Construction-IC

In the German residential construction market is characterized by a share of around 35%, in 2014 was valued EUR 44,431.8 million for new constructions, while Refurbishments and Maintenances have the biggest market shares in value terms, respectively EUR 39,475.8 million and EUR 33,917.7 million.

7.3.5 Considerations

The German Air conditioning Market especially in the residential sector is still immature, according to JARN report, this is proved by the penetration of air conditioning in the residential sector under 2 % in 2012.
Regarding the air conditioning market, splits are considered to be a high quality technology and this factor could bring these systems to an important spread in the next future. But also Movables have a quite important market share.

The heat pump market in Germany is very promising, despite the high electricity prices, Air/Water heat pumps have been increasing their market share in the last years, mainly in single-family houses for heating applications, and according to the study of the German Heat Pump association, in 2030 heat pumps will increase their market and the Air/Water solution will be the dominant one.

Hydronic systems can have in the next future in Germany a very deep penetration in the residential sector.

This trend is not even influenced by incentive programs.

The combination of electrically driven heat pumps and photovoltaic could be in the future a very interesting application.

According to the Entranze Project, the residential construction sector is characterized by a very high of owner occupied single-family dwellings while for multi-family ones is the opposite, it means that higher investments in heating or cooling systems could be expected in single-family houses. Half of the total residential dwellings are single-family houses and in the next years the residential construction market will be the fastest growing.

7.4 FRANCE

7.4.1 Introduction

France as the majority of European countries faced a difficult situation during the crisis period. GDP decreased by -2.9 % in 2009 and in 2011 faced austerity measures which influenced growth prospects. There are no signs of a fast economic recovery, it will be very slow. GDP values are still positive and prospects are of a slight growth.

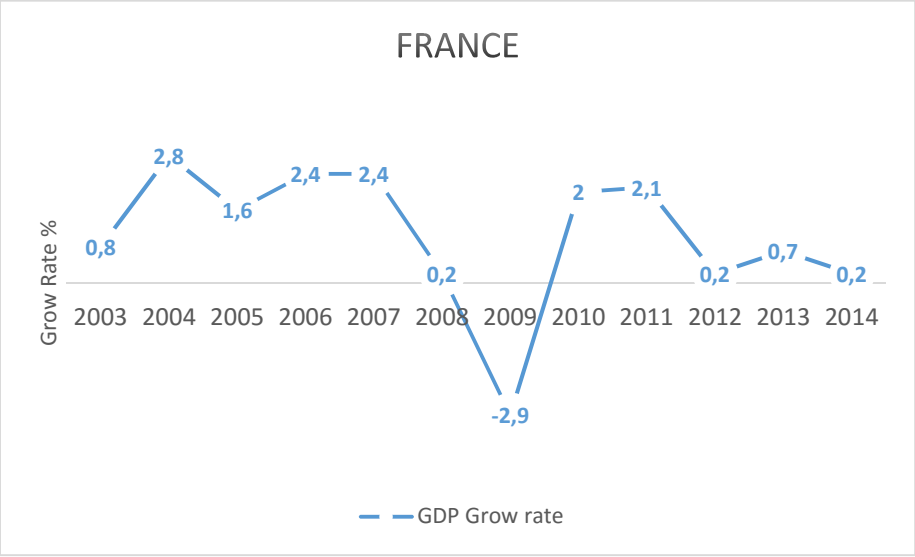


Figure 7.23: GDP Grow Rate in percentage, France – source EUROSTAT

The penetration of air conditioning in the residential sector was in 2012 around 9 % and according to JARN was expected to rise in the further period.

The climate in France is very various, three types of climate are found within France. An oceanic climate in the western part of the country, very low temperature ranges, cool summers and very cold winters. A continental climate in the Eastern part of the country and also in the Central part of it, characterized by warmer summers and cold winters. And a Mediterranean climate spread within Southern France with cool winters and hot summers.

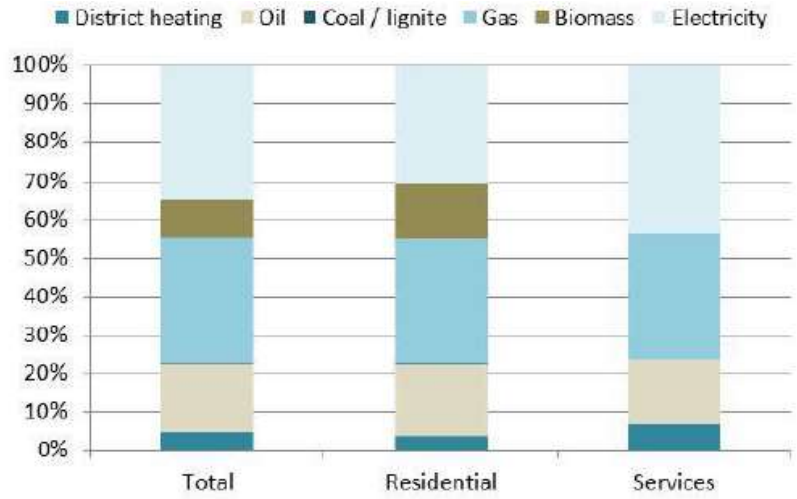


Figure 7.24: Total energy consumption of the building sector (2008) - source ENTRANZE Project, IEE

Electricity and natural gas are the dominant sources of energy in French buildings, accounting each of them around 33 % of the total.

Electricity is widespread as energy source in the domestic sector thanks to its very low price.

Space heating represents the largest share of household energy use, corresponding to an average of 70 % of the total energy consumption. Water heating accounts 10 % of the total consumption while Air conditioning represents a marginal share on residential energy consumption, however its distribution is slowly increasing.

Air conditioning in the service sector have a more significant penetration, assumed by JARN around 58 % in 2012.

7.4.2 The French Air Conditioner Market

The French was considered in 2004 a quite immature market but with a strong potential, the residential sector was expected to grow, but until now no remarkable signs were observed.

According to JARN the penetration in the residential sector on air conditioning is expected to reach over 20 % in 2016 but latest data do not confirm this prediction.

The French air conditioning market is a decreasing market since 2004 and in 2012 has not been indicating positive signs.

In 2003 the sales for windows were boosted by a very hot summer but they represented a still representing a very small share, in 2003 14,000 units and in 2012 the market was more than halved with around 4,000 units and it was supposed to remain quite stable.

The market for movables experienced in 2004 and in 2010 two significant increase on the sales. Reaching around 100,000 units sold in 2010 due to the heat wave. In 2011 sales fell to 33,000 units because of the cool summer. In 2012 it was considered to remain a fairly stable market with around 45,000 units.

Mini-split units have been since 2003 the biggest market, oriented mainly in the light commercial sector. Splits with < 7 kW power represented more than 70 % of the total market.

Sales for splits in 2010 accounted around 400,000 units, falling to 370,000 units in 2011 and in 2012 reaching 335,000 units. Prospects for 2013 were a further fall.

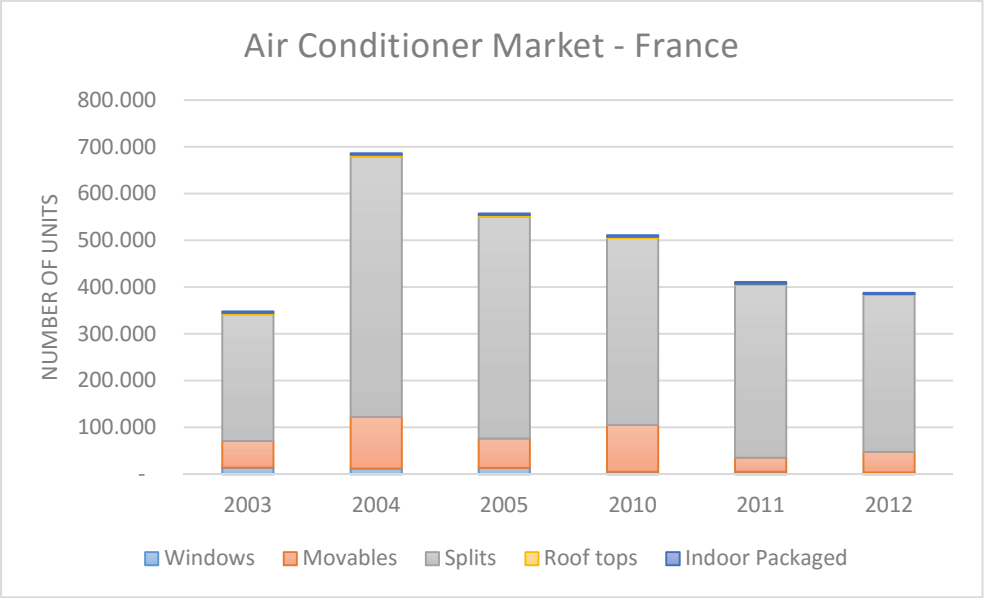


Figure 7.25: French Air conditioner Market – source BSRIA 2005, JARN 2012-2013

The VRF market in France in 2012 increased by 6 % over the previous year, counting around 15,000 units.

Sales for roof tops and indoor packaged have been establishing a quite stable market, and are mainly chosen in the commercial sector.

Data for chillers was not very clear, BSRIA's figures from which JARN built the report excluded small units (<20 kW) used as dedicated heat pumps in the domestic sector.

Sales for AHUs have remained quite stable, at an average 12,000 units over 2011 and 2012. Preferences are for models up to 1.5 m^3/s.

FCUs in 2011 were around 123,000 units, one of the biggest market in Europe after Italy. It was expected to increase.

The French underfloor radiant heating market counted in the two years 2008-2009 around 40 million of m^2 sold per year.

7.4.3 The French Heat Pump Market

The French Heat Pump Market has been a very interesting market since 2008, reaching the highest sales in 2009. 2010 was a quite difficult year, with a reduction on sales of around 50,000 units. In 2012 it has been showing a growth on sales reaching 142,000 units sold in the year. A rise about 1.8 % compared to 2011.

A new factor in the French heat pump market is the new regulation for new residential buildings, entered into force in January 2013. This regulation has the target to increase the application of heat pumps in new buildings, it will help also to reach the target of 23 % of RES in 2020.

Air/to Water heat pumps have reached a high level of market recognition even without incentive programs.

The hydronic heat pump's sector decreased by -4 % in 2012 compared to 2011 values. Air/Water heat pumps account more than 90 % of the total hydronic heat pump share.

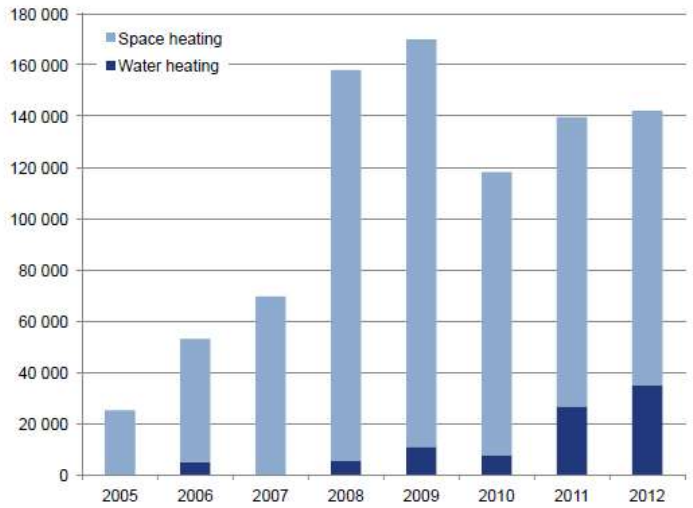


Figure 7.26: French Heat Pump Market Development 2005-2012 (number of units) – source EHPA Market and statistics report

MARKET TRENDS HEAT PUMP TECHNOLOGY

Heat Pump type	2009	2010	2011	2012	2011/2012 evolution
Air/Water	106,543	53,854	55,299	54,214	-2.0%
Water/Water	2,973	1,627	1,703	1,295	-24.0%
Brine/Water	6,969	2,968	3,589	3,593	0.1%
Direct Expansion/Water	1,291	454	507	658	29.8%
Air/Air (with main heating function)	30,115	34,597	34,279	31,709	-7.5%
Sanitary Hot Water	11,000	20,000	26,700	34,900	30.7%
Total	169,960	118,175	139,518	142,066	1.8%

Table 7.3: Market trends for heat pump type 2009-2012 - source EHPA Market and statistics report

After 2009 the Air/Water sales remained fairly stable around 55,000 units, as it is possible to notice from the table above. In the segment 5-10 kW, Air/Water heat pumps are mainly installed in new houses.

Ground source heat pumps is a decreasing market, a drop by 17 % in 2012 respect to 2011 values.

Sanitary hot water heat pumps increased their market share by 30.7 % within the two years 2011-2012 reaching 34,900 units sold. This growth has to be attributed to the construction of new houses with low energy demand and incentives on taxes.

Air/Air heat pumps with main heating application remained a stable market since 2009, reporting a reduction on sales of 7.5 % in 2012 respect to 2011.

The whole heat pump market did not perform very well except for SHW heat pumps, but it still grew by around 2 %.

In France, generally installers select products and recommend them to costumers and they have been recognizing the Air/Water heat pump as a high performance system.

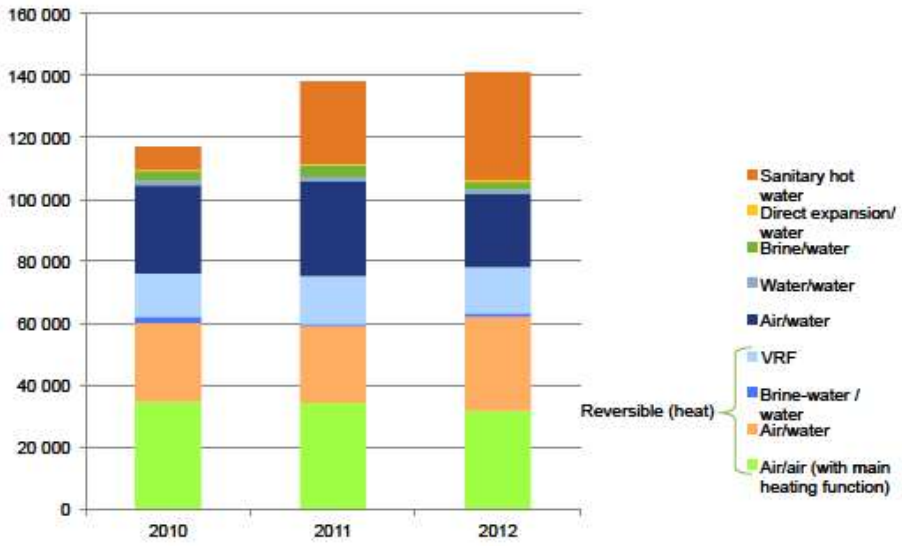


Figure 7.27: French 2009-2012 Market by type of heat pump - source EHPA Market and statistics report

Incentive programs were introduced in France, the subsidy works as a tax credit system. Part of the cost of the heat pump can be deducted from the taxes payed in the same year.

The incentive programs are supported by policies as the requirement of a minimum amount of renewable energy for multi-family houses, or the new building regulation which requires an amount of energy coming from renewable sources as heat pumps, part of the RES directive.

As for the German case also in France were introduced several pilot projects to test the integration of heat pumps in smart grids. Renewable energy systems, air/water heat pumps combined with a thermal storage were studied.

7.4.4 The French Residential Construction Market

The total French building area is around 3,400 million of m^2, 73 % of the total floor area is for residential dwellings and the rest is composed by service buildings. The main stakeholders in France are owner occupant of single-family houses, with 41 % of the total floor area.

Slightly more than half of the total residential buildings are single-family dwellings (56 % of the total). Average size for single-family dwellings is 112 m^2 while for multi-family ones is 66 m^2.

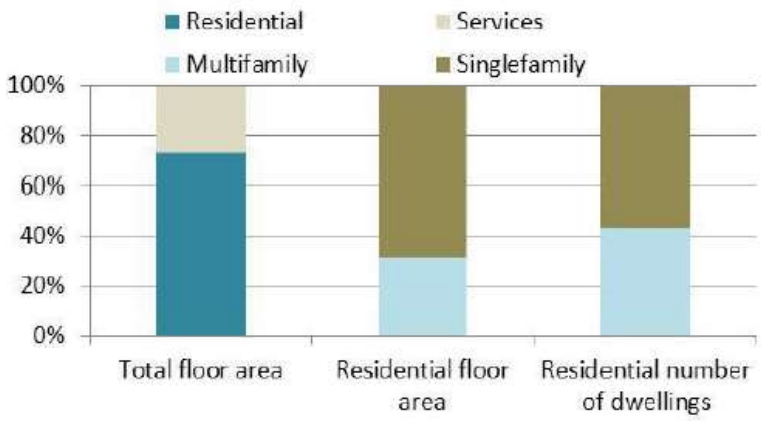


Figure 7.28: Figure x: Building by type - source ENTRANZE Project, IEE

In the first decade of 21st century 3.8 million of residential dwellings have been constructed, the construction market increased by 13 % per year between 2000 and 2007 and after 2008 it was deeply affected by the global crisis. Dwellings built after 2000 represent 12 % of the total stock.

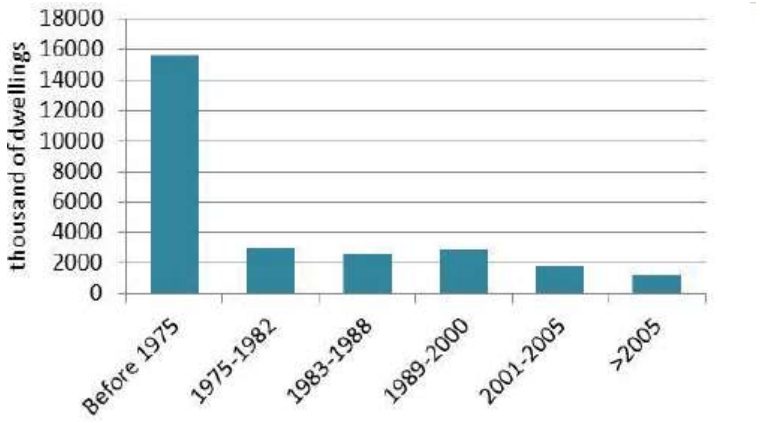


Figure 7.29: Residential dwellings according to construction date - source ENTRANZE Project, IEE

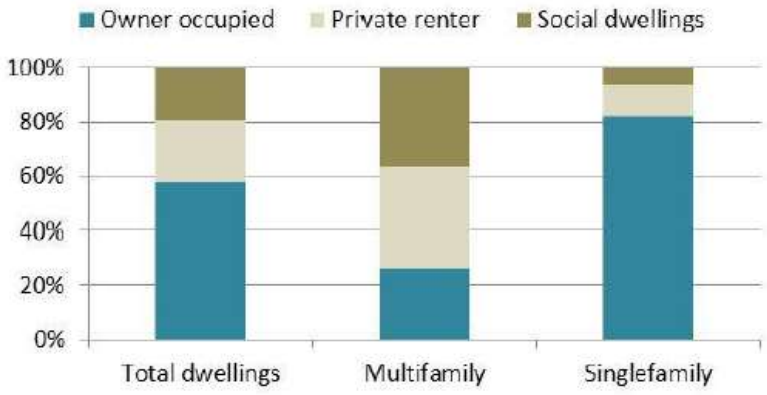


Figure 7.30: Breakdown of ownership and tenure - source ENTRANZE Project, IEE

During these ten years the share of multi-family dwellings increased from 35 % of total construction to 45 %, due to city urbanization.

In France, 43 % of the total dwelling stock existing in 2008 was built after 1975, 33% after 1982.

Owner occupants are dominant in the residential sector, 60 % of the total stock and in single-family houses the percentage is over 80 %, while in multi-family dwellings the percentage of owner occupants is 26 %.

The French construction market was valued EUR 268 billion in 2013 had the largest construction industry in Europe. It registered a low growth in 2009 of 1.5 % and declined by 4.2 % in 2010, following the Eurozone crisis. In 2010 the industry recorded again a decline, and registered a 2.8 % fall in 2013.

Over the forecasted period by CIC (2014-2018), due to better confidence in business, the construction industry is expected to sign a growth on CAGR of 1.47 %.

The residential construction market was the largest in France, accounting 44.3 % of the total industry in 2013, it is forecast to register a CAGR of 0.48 % reaching by 2018 EUR 121.8 billion.

Figure 7.31: French residential Construction Output by Project Type, 2009-2018 – source Construction-IC

Single-family housing category is projected to record a CAGR of -0.17 % over the forecasted period by CIC (2014-2018) and value EUR 57.5 billion by 2018.

Multi-family housing with a 51.2 % share was the fastest growing category within the residential construction industry. CAGR is expected to grow in the forecast period by 1.10 %.

Figure 7.32: French residential Construction Output by Activity Type, 2009-2018 – source Construction-IC

The French residential construction market has been and will be strongly pointed towards new constructions. In 2018 is expected to reach a value of EUR 92,231.9 million.

7.4.5 Considerations

Air conditioning still represents a marginal share of residential consumption, however the penetration of air conditioning has been expected to rise considerably up to 2016. In 2012 was the fifth European market accounting around 400,000 units in the year. Splits as usual are the technology mostly chosen, but in particular hot summers, movables' market increases.

The French heat pump market is one of the biggest in Europe, the particular low electricity price helped the spread of this technology, even without the help of incentives.

Air/Water heat pumps have the biggest share and are considered high performance systems. As in the case of Germany, France is a very promising market for hydronic systems to interface with Air/Water heat pumps.

Future incentive policies will increase the diffusion of this technology. The French construction market was the biggest in Europe in 2013.

The single-family housing market is expected to decline by a small percentage in the next few years, while the multi-family housing one has been the fastest growing market in the last few years and in the near future prospects are of a slight grow. The new construction segment will be the biggest accounting around 75% in value terms, about twice the value of the new construction segment in Germany.

7.5 SPAIN

7.5.1 Introduction

After a decade of very good economy performances, Spain has been facing a quite difficult economic situation since 2007. The growth trend was mainly driven by the construction sector which in 2007 started to be exposed to direct effects of the housing market status. The construction market turned into a crisis in 2008 and the whole economy was deeply affected.

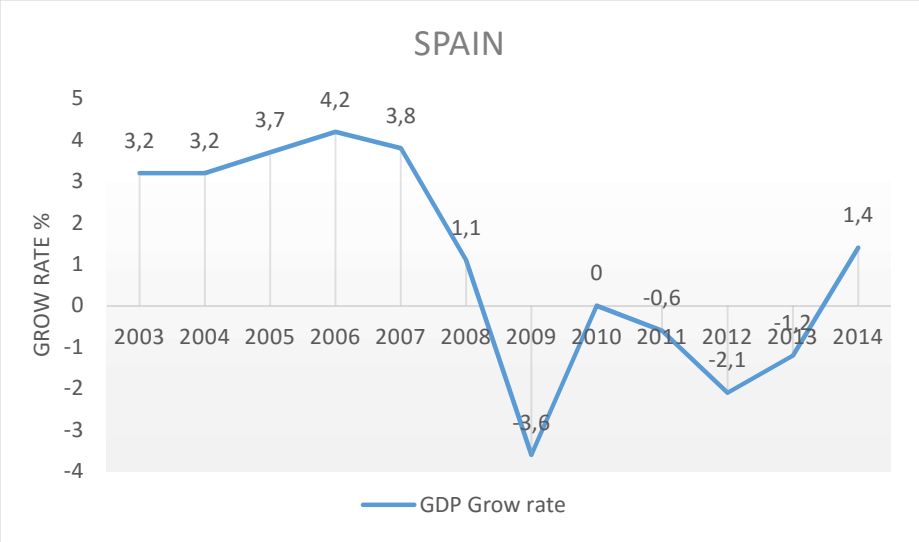


Figure 7.33: GDP Grow Rate in percentage, Spain – source EUROSTAT

In 2014, Spain started to recover from the crisis and prospects for 2015 are of a continuous growth on GDP values, however unemployment levels are very high.

Different climate regions can be found among Spain, Northern Spain has an Atlantic climate, with mild and hot summers while the South and the East of Spain have very hot summers and especially in Eastern part very high levels of humidity.

According to BSRIA, since 2005 the climate has been changing and nowadays temperatures around 22-23 °C can be found also in the months of May and September.

Electricity and oil are the dominant source of energy in Spanish buildings with around 46 % and 28 % respectively of the total market.

Space heating represents the largest share of household energy use corresponding to an average of 50 % of the total consumption. Water heating consumption represents the 26 % share of the total consumption while Air conditioning still represents a marginal share of the residential energy consumption around 1 %.

In the service sector air conditioning is more significant than in the residential sector. According to JARN the penetration of air conditioning in the residential sector was 44 % in 2012 and in the commercial one 72 %.

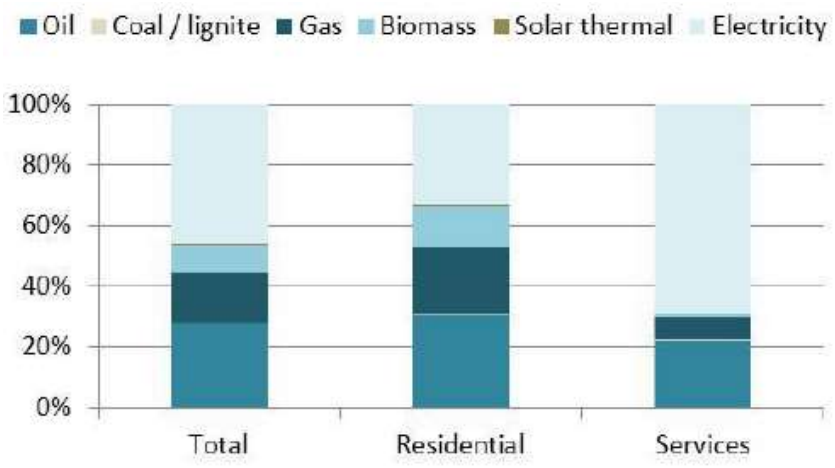


Figure 7.34: Total energy consumption of the building sector (2008) - source ENTRANZE Project, IEE

7.5.2 The Spanish Air Conditioner Market

The Spanish Air Conditioning Market was in 2004 one of the biggest in Europe, second after Italy, deeply guided by the residential sector. The whole market is guided by splits which have been accounting more than 90 % of the total market since 2003.

In 2012, the trend for the Spanish air conditioning market has been a continuous recession. The market counted in 2004 around 1,500,000 units sold in the year while in 2012 it halved with 610,000 units sold and prospects are not positive.

Windows have almost lost their market passing from 10,000 units sold in 2004 to 1,700 units sold in 2012 and they are mainly chosen for temporary applications.

Demand for movables deeply depends on the weather, this is why there was a sharp increase on sales in 2003 reaching around 20,000 units, and it is an increasing market especially in particularly hot summers as 2010 reaching the amount of 32,000 units. In the two years 2011 and 2012 the number of units sold decreased to 26,000 and 20,000 units respectively.

Splits accounted in 2004 around 1,400,000 units. In 2010 the total number of splits was 872,000 units, in 2011 the number of units decreased to 722,000 and in 2012 an additional fall to 573,000 units.

The main application for Mini-splits, since 2003 has been the residential sector and in 2012 accounted for about 70 % of the market value, ducted splits 20 % and the remaining part VRFs.

Indoor packaged have been in the three years 2010-2012 very popular for commercial applications with around 11,300 units sold in 2012 and it is a slightly increasing market.

Roof Tops have been applied mainly for refurbishments of existing units in commercial applications.

The Chiller market has been also decreasing during the forecast period from 9,000 units sold in 2004 to around 3,500 units sold in 2012. A continued demand for hydronic cooling has helped to increase sales of the smaller units.

Sales for AHUs decreased in the three years 2010-2012 and in 2012 to reach 8,000 units. AHUs are mainly used in the commercial sector, not in the residential one.

FCUs accounted in 2010 sales for 69,000 units, falling to 59,000 units sold in 2012.

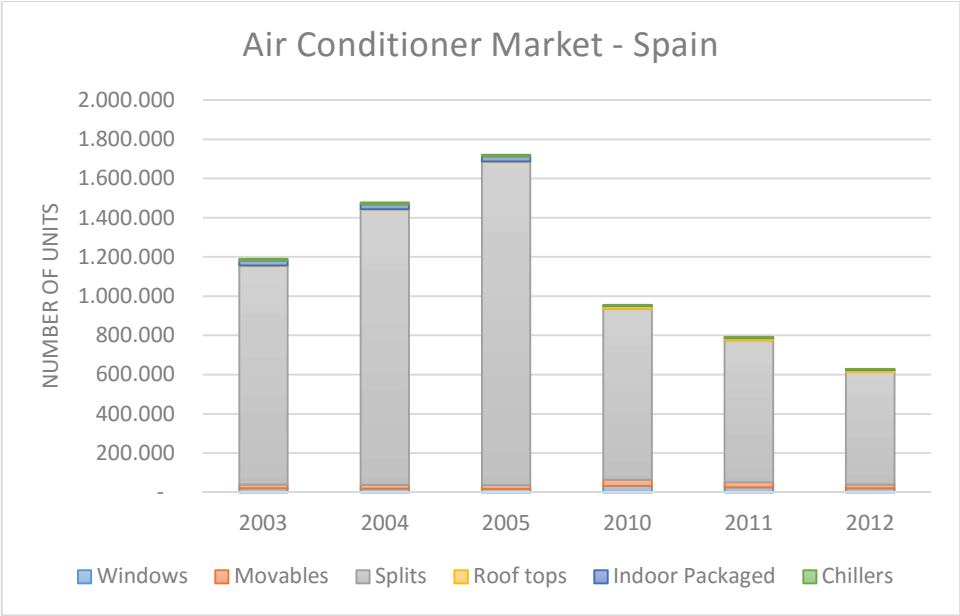


Figure 7.35: Spanish Air conditioner Market – source BSRIA 2005, JARN 2012-2013

7.5.3 The Spanish Heat Pump Market

The Spanish heat pump market showed a decrease in 2012 of more than 30 % compared to 2011 values. In the residential sector in value terms the market in 2012 was EUR 241.3 million while in 2011 was EUR 308.6 million, a decrease by 21.8 %. Heat pumps are the main technology for heating in the commercial sector whereas in the domestic sector, gas boilers is the main heating source for single-family dwellings and central heating systems for multi-family buildings.

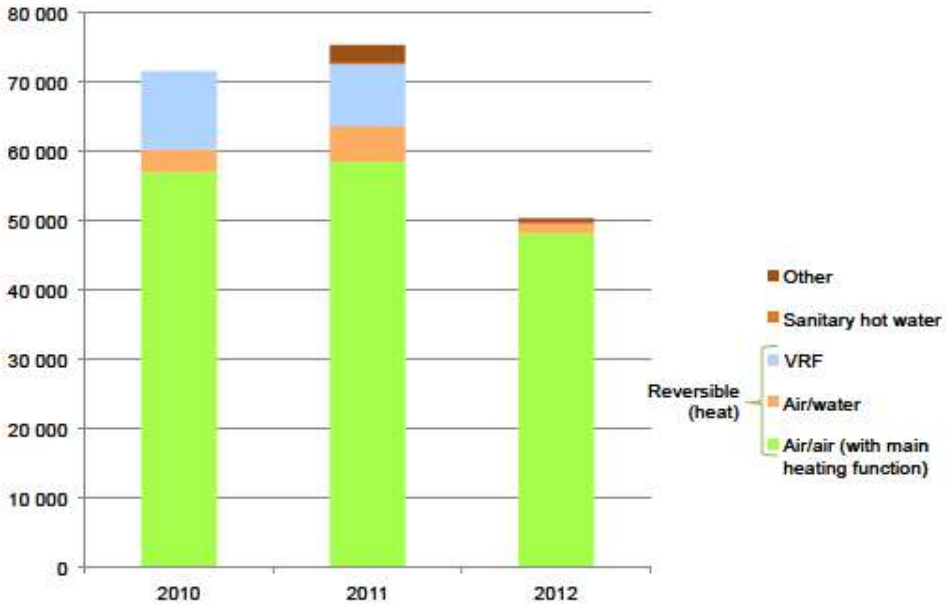


Figure 7.36: Spanish 2010-2012 heat pump market evolution by type - source EHPA Market and statistics report

Air/Air heat pumps for heating applications are not very widespread, except for Southern Spain, where they are used combined with electric boilers and used mainly for cooling applications. The need for heating is considered less necessary than the need for cooling.

Ground source heat pumps have been expanding during the last few years, however the cost is still very high. Incentive programs with the purpose of promoting ground source heat pumps was introduced in Spain some years ago.

On the other hand, no other incentive programs are expected for the promotion of Air/Air heat pumps.

MARKET TRENDS HEAT PUMP TECHNOLOGY

Heat Pump type	2010	2011	2012	2011/2012 evolution
Reversible systems (MHF)	71,616	72,658	49,625	-31.7%
Hydronic heat distribution (W/W)		2477(387)	511(511)	-79.4%
Sanitary Hot Water		257	282	9.7%
Total	71,616	75,392	50,418	-33.1%

Table 7.4: Market trends for heat pump type 2009-2012 - source EHPA Market and statistics report

In addition to this, the incentive plan "Planes Renove" was introduced by regional governments to promote the substitution of old inefficient air conditioners with new "A class" ones.

The programs are structured in the form of subsidies in the range of € 150-350 per unit.

7.5.4 The Spanish Residential Construction Market

The total building area in Spain is around 1,917 million of m^2, 82 % of the total share is associated to residential dwellings. 65% of the total floor area is covered by multi-family buildings while the 35 % by single-family dwellings. Of the total dwelling stock, about 68 % is composed by main homes and the rest by secondary homes.

Average size for a single-family dwelling is 111 m^2 while for multi-.family ones is 22% smaller with an average size of 86 m^2.

Regarding the space heating consumption, a single-family house consume on average 27 % more per m^2 than a multi-family dwelling.

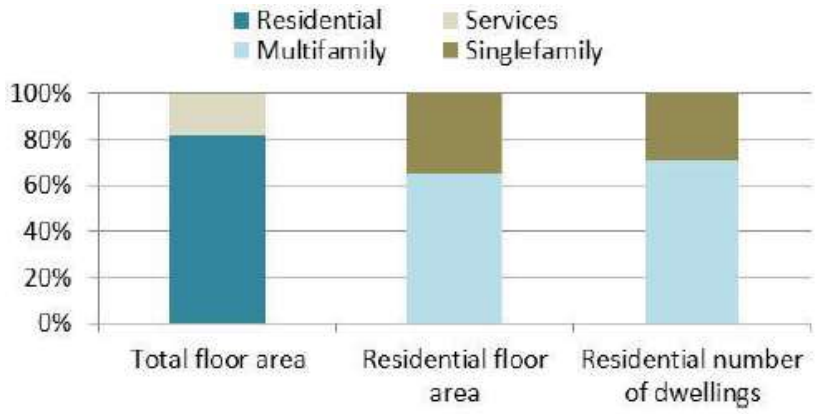


Figure 7.37: Building by type - source ENTRANZE Project, IEE

Around 80 % of the total housing stock is occupied by the owners.

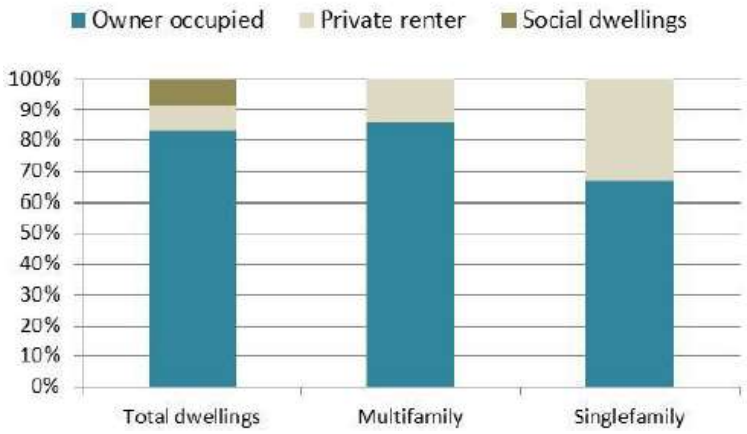


Figure 7.38: Breakdown of ownership and tenure - source ENTRANZE Project, IEE

As previously mentioned, the construction market in Spain has been increasing between 2002 and 2007 by an average of 12%/year and after 2007 it has been facing a deep crisis, decreasing on average by 40 % per year.

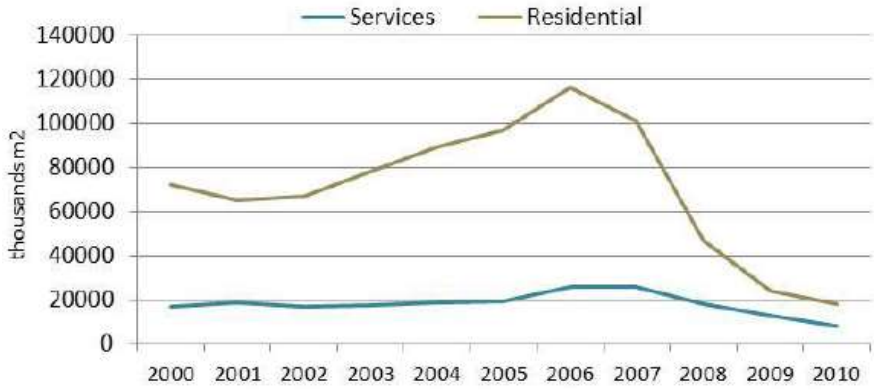


Figure 7.39: Dynamics of building construction market 2000-2010 - source ENTRANZE Project, IEE

According to CIC in early 2015 the Spanish construction market showed positive signs, mainly in the residential construction market and over forecast period (2015-2019) the market is expected to grow by an average annual compound of 2.72 %. The industry during the reviewed period (2010-2014) by CIC recorded an annual decline by 7.1 %.

Figure 7.40: Spanish residential Construction Output by Project Type, 2009-2018 – source Construction-IC

In 2014 the residential construction market registered a slight decrease, by 0.1 %, with a value of EUR 47.5 million it was the biggest market in the Spanish construction industry in 2014.
The market in the next future is expected to register the fastest growth over the forecast period at a CAGR of 5 %, to reach in 2019 a value of EUR64.1 million.

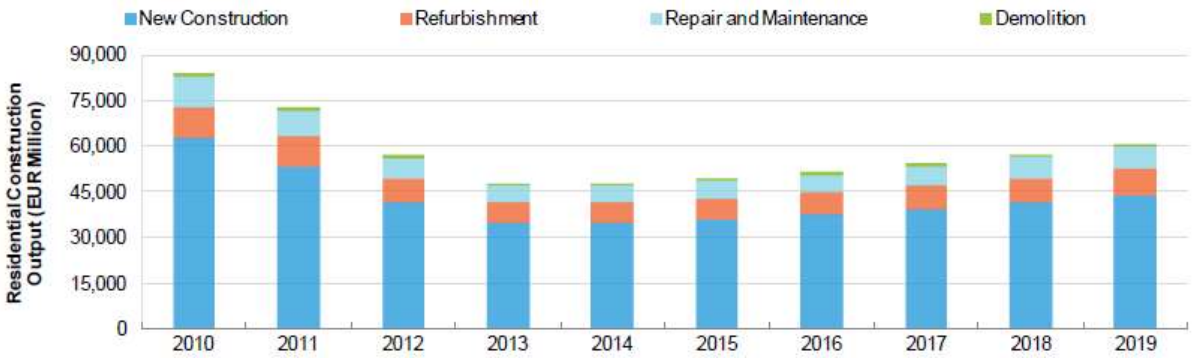


Figure 7.41: Spanish residential Construction Output by Activity type, 2009-2018 – source Construction-IC

The new construction activity is expected to reach in value terms EUR 43,929.5 million in 2019, around 75 % share.

7.5.5 Considerations

Spain has been facing, as any other Southern European country, a very hard economic crisis. Recovery prospects seems to be quite hard at least in the short term.
Climate conditions are probably the most favorable conditions in Europe for a very high distribution of cooling systems, also because climate is changing towards hotter and longer summers.
Nevertheless, the air conditioning market was deeply influenced by the economic crisis and in the last ten years has more than halved in term of number of units sold, and this fall is not intended to be stopped.
Splits still remain the most widespread cooling technology, so much which has been the second biggest market in Europe in 2004. Mini-splits are used in the southern part of the country for heating applications, and it seems to have very interesting prospects.
Movables, as for other cases, increase their market shares mainly in particularly hot summers.
The Spanish economy strongly depends on the construction market, latest information report of a slight grow of the residential construction market in the first quarter of 2015, and in the next few years, according to CIC it will be the fastest growing market in the Spanish construction industry.

7.6 UNITED KINGDOM

7.6.1 Introduction

The United Kingdom economy has been growing continuously since the 1990s until 2008 experiencing the longest period of uninterrupted growth. The financial crisis ended this long period of prosperity, GDP decreased before in 2008 by 0.3% and then by 4.3% in 2009.

The UK is part of the European Union but maintained economic sovereignty, its currency is the Pound Sterling (GBP). Its economy is almost completely based on finance and during the last years UK is experiencing a new period of growth.

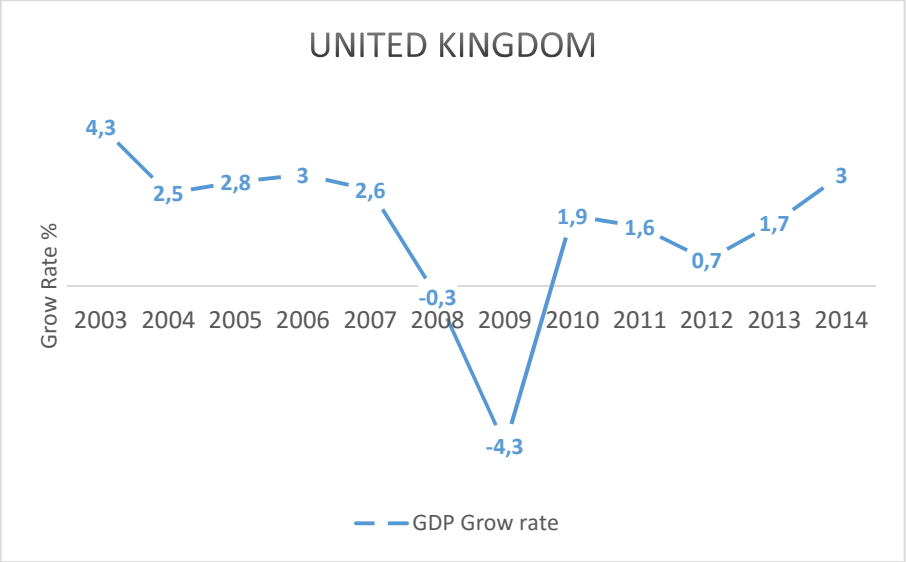


Figure 7.42: GDP Grow Rate in percentage, UK – source EUROSTAT

The air conditioning market is mainly centered on the commercial sector where air conditioning had a penetration of 42 % in 2012. Air conditioning in the residential sector is seen as a luxury item for fancy apartments or houses, in fact the penetration in this sector is around 3 %.

The climate is temperate and the need for heating last from October until March and sometimes also September and March are included. However, according to BSRIA, higher temperatures are expected and also rising sea levels, due climate changes.

According to the DECC[4] Natural gas and electricity were the main source of energy by consumption in 2014 with a share respectively of 62 % and 25 %.

Domestic consumption is the second highest demand for energy in UK. Space heating represents the biggest share for the domestic consumption accounting 60 % of the total followed by water heating with a share of 24 %.

Air conditioning represents a very small share while in the commercial sector is slowly increasing.

Electricity and oil are the dominant source of energy in Spanish buildings with around 46 % and 28 % respectively of the total market.

[4] DEEC (Department of Energy and Climate Changes)

Space heating represents the largest share of household energy use corresponding to an average of 50 % of the total consumption. Water heating consumption represents the 26 % share of the total consumption while Air conditioning still represents a marginal share of the residential energy consumption around 1 %.
In the service sector air conditioning is more significant than in the residential sector. According to JARN the penetration of air conditioning in the residential sector was 44 % in 2012 and in the commercial one 72 %.

7.6.2 The UK Air Conditioner Market

The UK has been since 2003 a market addressed to the commercial sector. The residential one is mainly covered by the movable technology.
The market for windows has been a stagnant market in the first three years of the forecast period while in the 2010-2012 period it has been diminishing and prospects are a stabilization to around 600 units, a very small market.

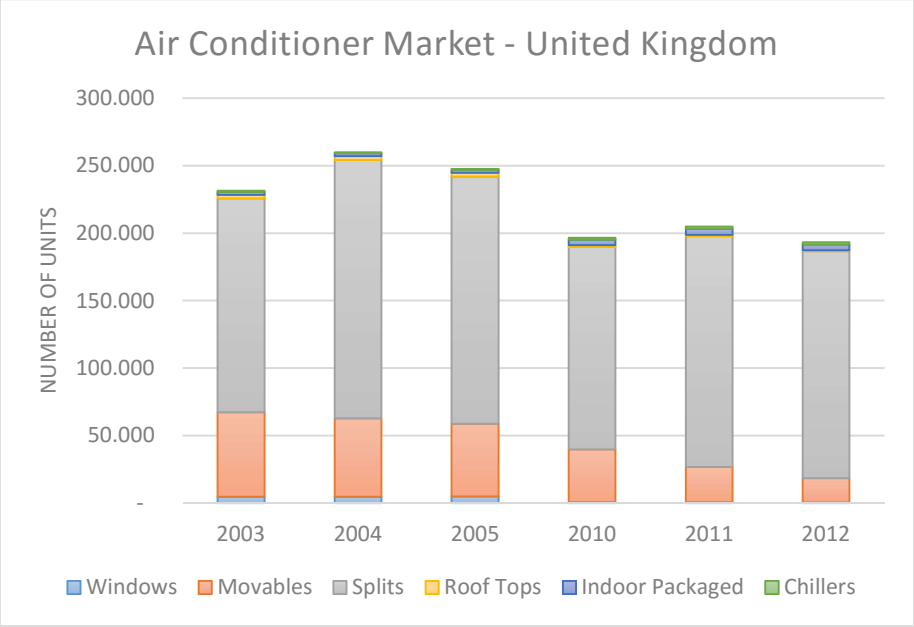


Figure 7.43: UK Air conditioner Market – source BSRIA 2005, JARN 2012-2013

Movables represented in 2004 a 22 % share of the total market accounting 58,000 units sold in the year. The market has for movables has been decreasing, reaching around 18,000 units sold in 2012. This technology is mainly chosen during particularly hot summers.
Splits have been the favorite solution since 2003, accounting 191,000 units sold in 2004. The market has been quite stable, in 2012 168,000 units were sold.
In 2004 the market was dominated by single-splits with a 90 % share in term of numbers while multi-splits have a very small share (4 %). Just over a third of the total splits were under 5 kW and a quarter of them were over 10 kW. A demonstration of the very small penetration in the residential market.
In 2012, the total value of the split market was around US$ 480 million of which US$ 220 million was in the form of VRF systems and in term of numbers 15,000 VRF units were sold in the year. The second largest market in Europe.

Sales for roof tops were in 2004 around 2,800 units, the market for these systems has been decreasing constantly, reaching in 2012 800 units sold and it will remain to that amount. Mainly used in retail sectors.
In 2012 were sold around 4,300 of indoor packaged units and most of them were used to replace high splits for commercial applications.
The market for chillers with power (<100 kW) has been an increasing one, passing from 800 units sold in 2003 to 1,500 units sold in 2012 and it is considered to remain a stable market in the next few years.
The market for AHUs is destined to grow in the years, in 2012 it accounted 17,000 units sold. Demand for mini units has been increasing in recent years due to the need for fresh air ventilation in sealed buildings.
The market for FCUs accounted around 50,000 units sold in 2012 and it is sustained by the demand for replacements and refurbishments.
Underfloor radiant heating systems counted in 2009 21.9 million meters sold in the year.

7.6.3 The UK Heat Pump Market

The UK heat Pump market has been an increasing market since 2005 up to 2010 and even in the period of the financial crisis it has been marking very positive signs. From 2011 the market suffered a small contraction ending in 2012 with a fall by -3.4 % compared to values of the previous year but it is expected to maintain positive signals in the following years.
The complete market accounts 17,869 units sold in 2012, it still is a very small market compared to the boiler market which accounted more 1.5 million of units sold in the year.
The heat pump market in UK is completely dominated by Air sourced heat pumps counting a share of 87 %. Air sourced heat pumps experienced a contraction on the sales by 4.8% due to the reduction of exhaust Air/Air heat pumps.

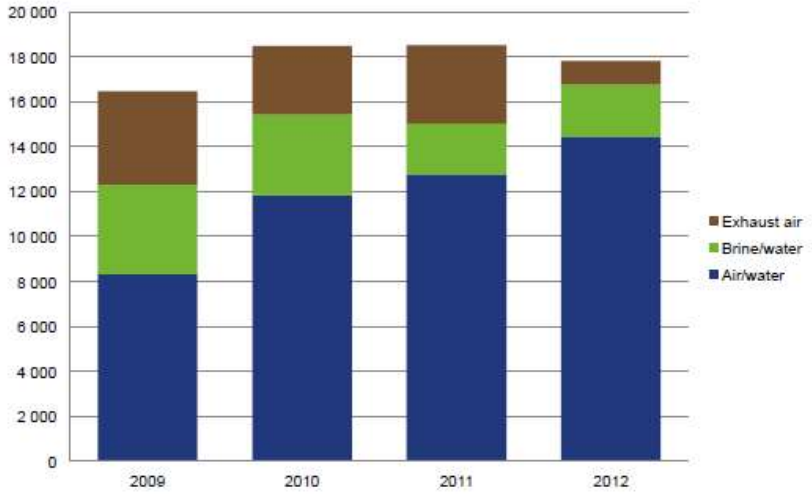


Figure 7.44: UK Heat Pump Market Development 2005-2012 by type (number of units) – source EHPA Market and statistics report

Air/Water heat pumps have been showing during the forecast period very positive signs. A constant growth was observed, and the expectations are very high for this technology.
The penetration of the heat pump technology in UK is significantly lower than other European countries as France, Italy and Germany.

Political support in UK underlines the importance of heat pumps in the future with the purpose of improving energy efficiency in buildings and reducing CO_2 emissions.

Incentives will play an important role in the next future, the introduction of RHI[5] for residential applications in 2013 will push the spread of heat pumps technology.

MARKET TRENDS HEAT PUMP TECHNOLOGY

Heat Pump type	2009	2010	2011	2012	2011/2012 evolution
Air/Water	8,325	11,840	12,765	14,455	13.2%
Geothermal	3,980	3,850	2,255	2,294	1.7%
Exhaust Air/Air	4,150	3,050	3,480	1,050	-68.9%
Sanitary Hot Water				70	
Total	16,455	18,740	18,500	17,869	-3.4%

Table 7.5: Market trends for heat pump type 2009-2012 - source EHPA Market and statistics report

The RHI is an incentive program structured as a payment system for the generation heat from renewable energy sources. The domestic RHI program provides for a payment for generating heat from heat pumps, thermal panels or biomass and depending on the typology the consumer would receive a payment back for each kWh of produced energy. For instance:

Air source heat pumps	7,3 p/kWh
Ground source heat pumps	18,8 p/kWh
Biomass boilers	12,2 p/kWh
Solar thermal	19,2 p/kWh

The primary energy source, as previously mentioned, to provide heating in UK is Natural Gas, Gas boilers is the main technology. The goal of the energy policy strategy is to change the primary energy consumption from gas to electricity through the spread of heat pumps.

7.6.4 The UK Residential Construction Market

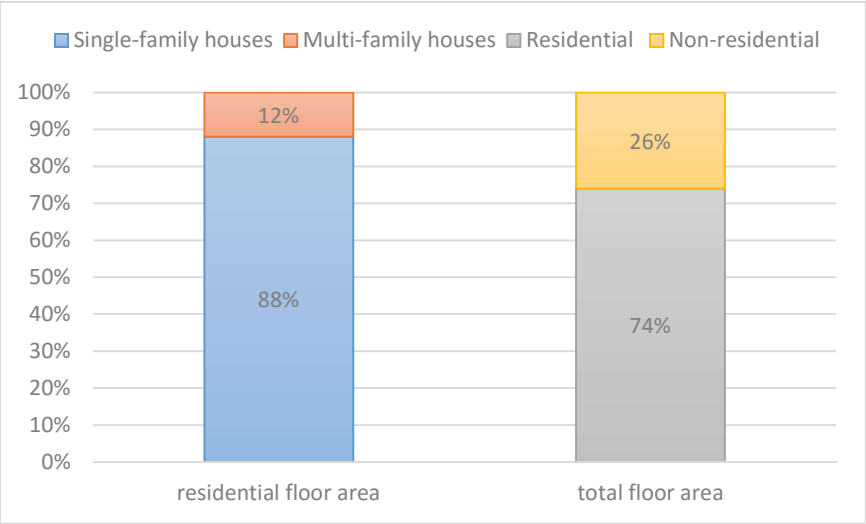


Figure 7.45: Building by type – source Europe's building under the microscope, BPIE

[5] RHI (Renewable Heat Incentive)

Of the total building area in UK, 74 % is associated to residential buildings. 88 % of the total floor area for the residential sector is covered by Single-family dwellings and the rest by Multi-family ones.
Private owners are dominant in the residential sector, with a 69 % share.

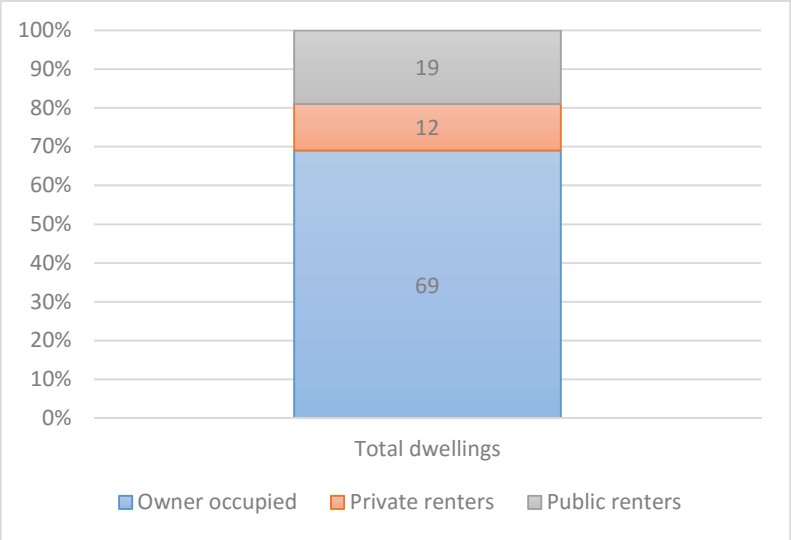


Figure 7.46: Breakdown of ownership and tenure – source Europe's building under the microscope, BPIE

The Construction Intelligence Center (CIC) studied the UK construction over the period 2010-2014 recording an average annual expansion of 0.45 %. Over the forecast period (2015-2019) the industry is expected to perform really well increasing at an average percentage of 4.19 %. Increasing in value terms from US$ 184.7 billion in 2014 to US$ 229.7 billion in 2019.
The residential construction market was the largest market in the construction industry, with a of 40.6 % share in value terms in 2014. The market recorded an increase on CAGR of 6.77 % in reviewed period as it is possible to notice from the figure below, with a value of US$ 89.9 billion in 2014.
The market is expected to maintain the same share in forecast period, significant investments in residential projects and government initiatives will guide the growth of this sector.

Figure 7.47: UK residential Construction Output by Project Type, 2009-2018 – source Construction-IC

Moreover, the growing population and low interest rates will support further the expansion of this sector.

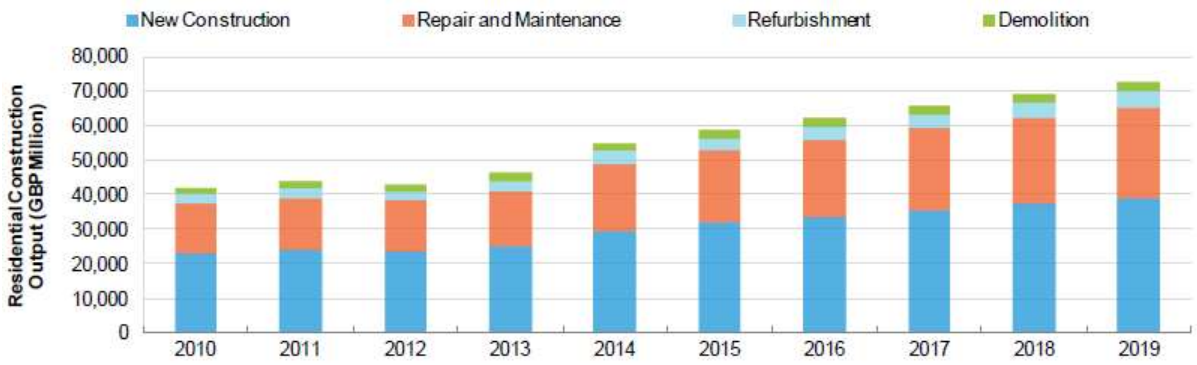


Figure 7.48: UK residential Construction Output by Activity Type, 2009-2018 – source Construction-IC

The new construction activity is expected to reach in value terms around GBP 38,925.5 million in 2019. Maintenance will be the second activity which is expected to perform in the residential construction market, in 2019 is expected to reach in value terms GBP 26,491.3 million.

7.6.5 Considerations

The United Kingdom does not have an advantageous climate for the diffusion of air conditioning. The residential sector appears to be very far from saturation and in particular air conditioning is seen as a luxury item for expensive houses. On the other hand, the commercial sector has a very high penetration, much to represent the second biggest market in Europe for VRFs.

The UK heat pump market is not a very big market compared to other similar European countries in Europe as France or Germany. It represents around one eight of the French heat pump market and it is still very far from the boiler market which counts 1.3 million of units sold.

The Air/Water heat pumps also in UK are representing the most promising market. Government policies as RHI are pushing to a higher spread of heat pumps and the goal of the national energy policy strategy is to change the primary energy consumption from gas to electricity.

In UK 88 % of the total floor area is covered by Single-family houses. The residential construction market has been growing in the review-period (2010-2014) at a higher percentage compared to the total construction market and is expected to grow in the forecast period (2015-2019) by 5.9 % and to value in 2019 US$ 110.8 billion.

7.7 GREECE

7.7.1 Introduction

Greece represents the 10th most populous European country, with around 10,800,000 inhabitants. The economic situation in the latest years has been very difficult and after seven years of recession the economic recovery seems to be very far. Greece is the country that have suffered the most the crisis of the Eurozone. Despite the GDP grow rate in 2014 performed positively the situation among the country is very hard, the unemployment percentage is around 24.8 % in 2015.

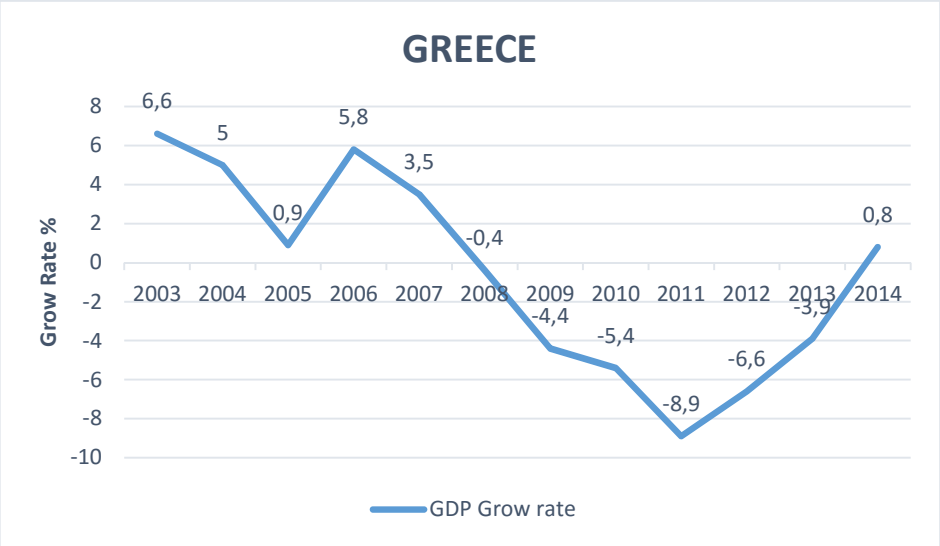


Figure 7.49: GDP Grow Rate in percentage, Greece – source EUROSTAT

The penetration of air conditioning in the residential and in the commercial sectors was quite high around 48 % and 55 % respectively in 2012.

According to JARN report, by 2016 these figures should reach a penetration of 55 % and 65 %.

The climate in Greece is typically a Mediterranean climate with very warm and dry summers and mild but rainy winters. Spring and autumn are usually short seasons.

7.7.2 The Greek Air Conditioner Market

The Greek air conditioning market was since 2003 a very big market if we consider the number of inhabitants and the total floor area of the country. Air conditioning is considered a necessity rather than a luxury in both commercial and residential sectors.

The Greek Market has been dominated by splits since 2003, it was considered the highest market per capita in Europe, accounting in 2004 around 560,000 units sold in the year. In 2004 Greece was the third biggest market for splits in Europe counting around the same number of splits sold in France.

In the figure above is showed only the evolution of the market for Splits because there are no significant data regarding other technologies since 2003. Almost all the market is covered by this technology.

Windows and movables have been losing popularity mainly because the price for splits is often cheaper.

The market for splits has been decreasing during the reviewed period. Sales for splits fell from 560,000 units sold in 2004 to 300,000 units in 2010 and again to 216,000 in 2011. But then rose again in 2012 to 317,000 units. A market of around US$ 210 million.

Single-splits dominate the market, multi splits accounted in 2012 3 % in value terms, while ducted and VRFs 15 % of the total value.

Figure 7.50: Greek Market for Splits – source BSRIA 2005, JARN 2012-2013

The increasing oil prices are pushing to switch to electric heating in winter, therefore heat pump function split units are also used for heating functions.

Chillers sold in 2012 were around 1,000 units and most of them are small machines (<100kW) and often used for domestic cooling.

In 2012 sales for AHUs accounted around 1,000 units.

Talking about FCUs 23,000 units were sold in 2011most of them for renovation applications in offices or in public buildings.

Regarding the heat pump market no market data was available.

7.7.3 The Greek Residential Construction Market

The total building area in Greece is estimated to around 450 million of m^2, 72 % of the total share is associated to residential dwellings. 12 % of the total floor area is covered by multi-family buildings while the 88 % by single-family dwellings.

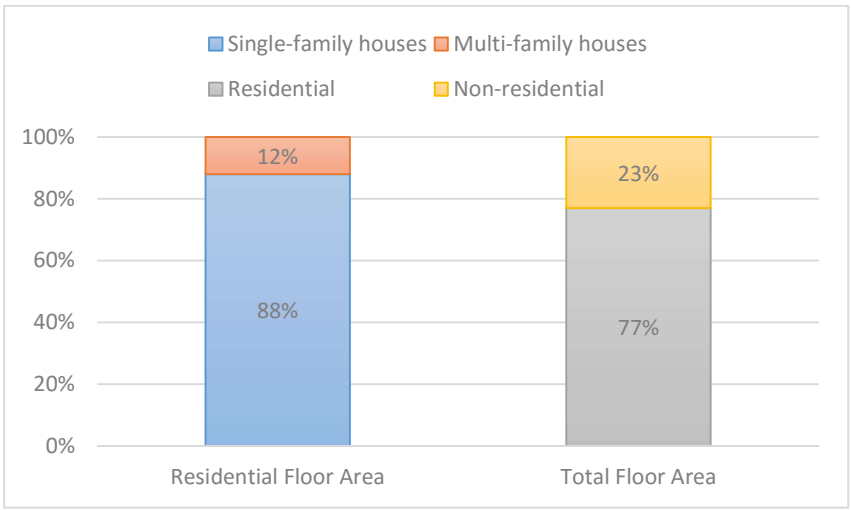


Figure 7.51: Building by type – source Europe's building under the microscope, BPIE

The majority of the buildings around 65 % was constructed before 1980.

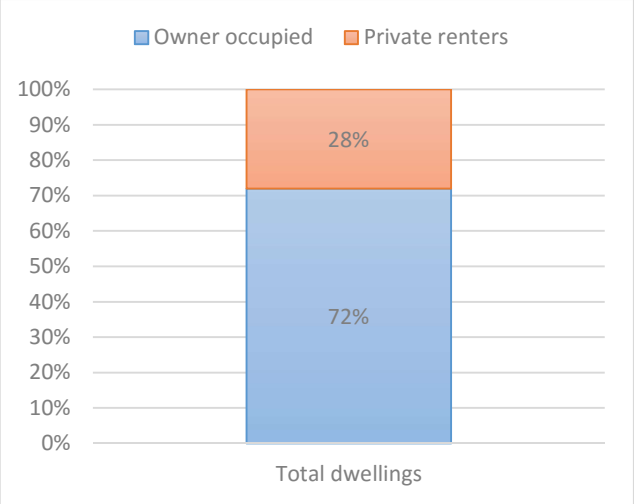


Figure 7.52: Breakdown of ownership and tenure – source Europe's building under the microscope, BPIE

According to CIC the Greek construction industry recorded a CAGR of -21.55 % during the review period (2009-2014) and valued EUR 11.9 million in 2013.

The whole construction market was deeply affected by the Eurozone crisis. The construction industry is expected to remain stable, in the forecast period (2015-2018) CAGR will record a 0.02 % and to maintain more or less the same market value in 2018 of 2013.

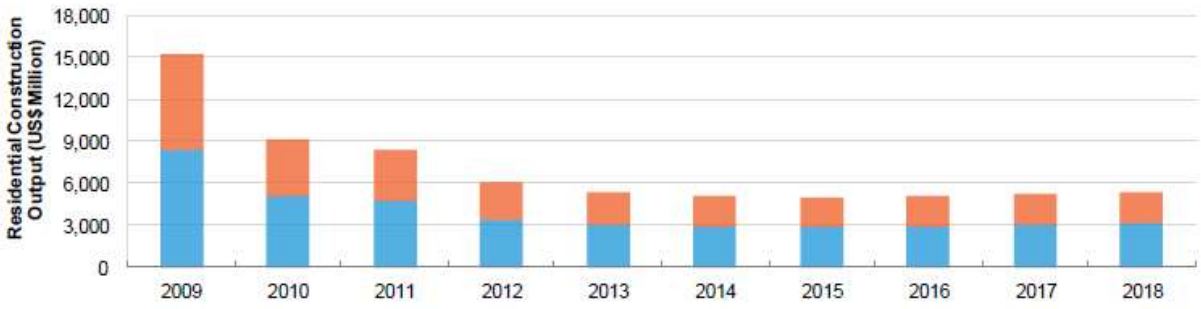


Figure 7.53: Greek residential Construction Output by Project Type, 2009-2018 – source Construction-IC

The residential construction market was the largest market in 2013 with a market share of 33.9 % and a value of EUR 4.0 billion.

The market recorded a CAGR of -12.82 % during the reviewed period. The demand for housing has been falling due to the increase in the real property taxes. The market is expected to perform in the forecast period a CAGR of -0.82 % to reach a value of EUR 3.9 billion in 2018.

Single-family housing recorded a CAGR of -22.93 % during the review period. In the forecast period prospects for single-family housing are a CAGR of -1.28 % and reaching a value of EUR 1.6 billion in 2018.

Multi-family houses on the other hand, with a 56.8 & share in 2013 was the largest category within the residential construction market during the review period. Multi-family housing construction is expected to value EUR 2.2 billion in 2018, a –0.48 % in the forecast period.

7.7.4 Considerations

The economic situation in Greece is dramatic, and the prospects seem very dark.
The Greek climate is very favorable for the spread of air conditioning, indeed the penetration of air conditioning in the residential and in the commercial sectors is very high. In 2012 was 48 % and 55 % respectively.
The need for cooling is seen as a necessity not a luxury item.
The air conditioner market is stable and almost completely covered by split units, in the residential sector mainly all single-splits. Furthermore, the boost of oil price (the main energy source in Greece) pushed consumers to use for heating application reversible split units.
The construction market did not perform very well in the last years and it is not expected to do so in the next few years.
In general Greece cannot be considered a dynamic market, splits in my opinion will continue to own the market also in the future and they will also be used more and more for heating applications.

7.8 RUSSIA

7.8.1 Introduction

The Russian Economy is still experiencing the deep transformations that followed the fall of the URSS and its economic system.

The primary economic sector is the agriculture followed by industry and the financial sector. However Russia is the first State in the world for the production and the reserves of mineral and energy resources.

Russia is a major exporter of its natural resources.

Russian economy has been growing over the years before the financial crisis, this growth was driven mainly by energy exports. It increased the oil and gas productions.

Currently Russia is facing a difficult situation, after the financial crisis in 2010 the fall was balanced by a 4.5% growth but after that, Russian economy suffered a continuous decline and latest data for Russian GDP report a decline on GDP by 3.4 % only in the first half of 2015 and Russia is considered in this moment the less productive country in Europe according to OECD[6] data.

Russia still has the lowest unemployment rate in the world.

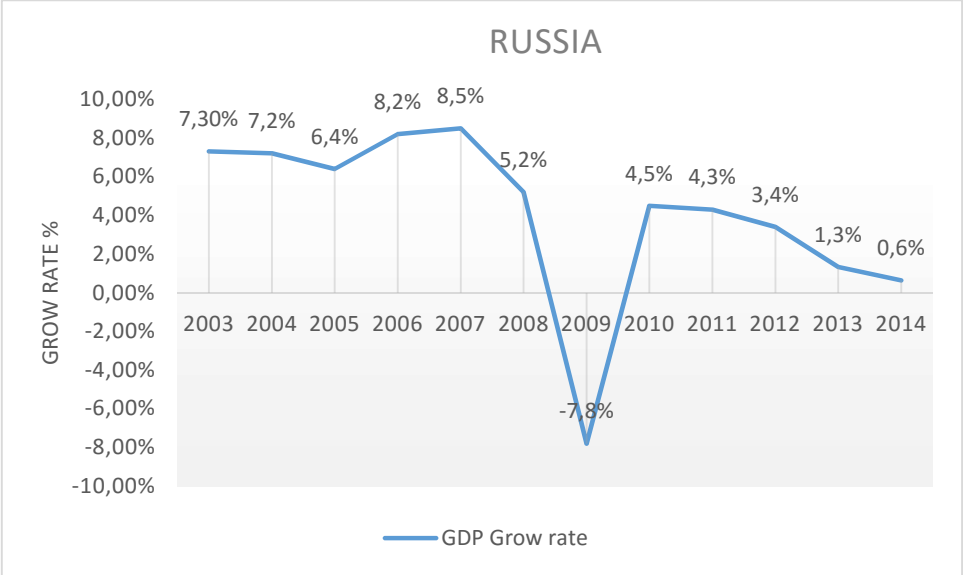


Figure 7.54: GDP Grow Rate in percentage, Russia – source World Bank

Russia is characterized by very rigid climate and low humidity, winter is very long and cold while summer is quite brief and rather warm. In summer, the warm and humid air reaches up to Siberia but still southern Russia is the one with warmest climate. Winter is everywhere quite rigid, and Siberia is the coldest zone.

Natural gas is the dominant energy source in the Russian domestic sector and with its extensive natural gas network covers the whole country. However electricity market is also changing.

[6] Organization for Economic Co-operation and Development (OECD)

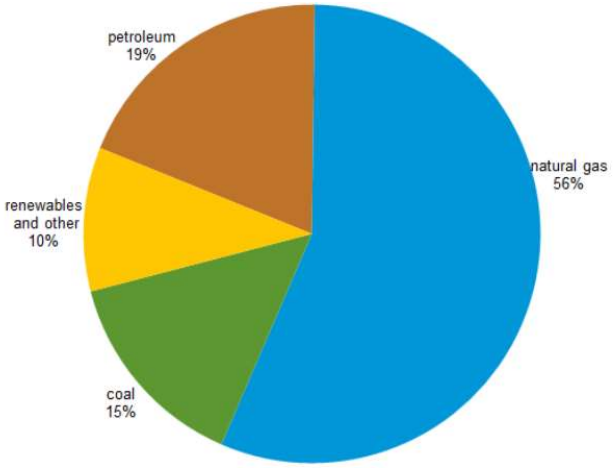


Figure 7.55: Total Energy consumption in Russia by type, 2011 – source EIA

Space heating represents the largest energy use in the residential sector, accounting 85 % of the total share, it is followed by electricity consumption with a 14 % share.

7.8.2 The Russian Air Conditioner Market

The Russian Air Conditioning market was the sixth market in Europe in terms of number of units sold. It became the first market in 2011 reaching more than 2,000,000 units.

The Russian Air Conditioning market started to become an interesting market in the early 1990s. The commercial sector has been increasing the demand for air conditioning systems and only after a decade the market moved also to the residential sector.

In 1998, LG and Samsung introduced a Window AC unit with a price considerably lower than the cheapest of other competitors and this fact has led to an increase on the demand in Southern Russia. The market since then has been growing.

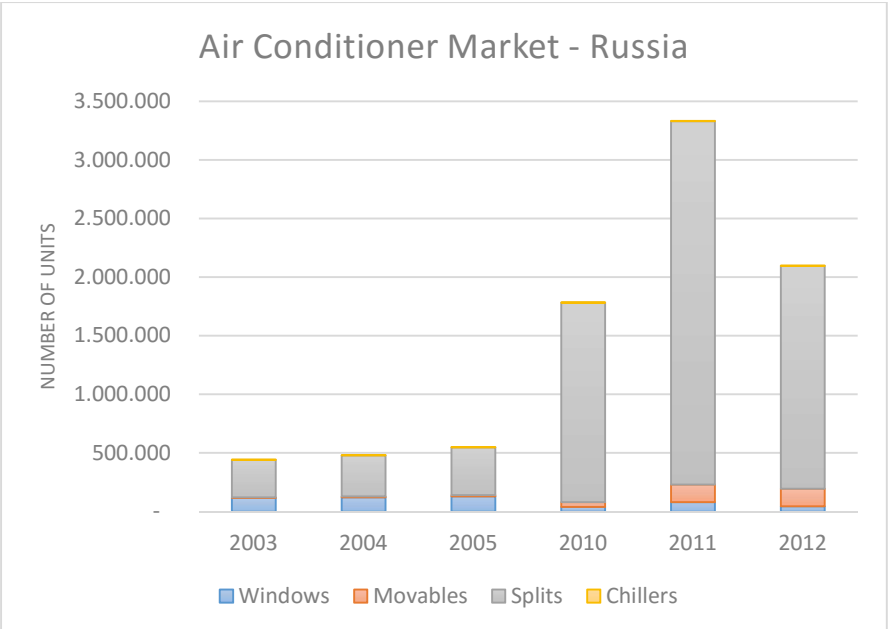


Figure 7.56: Russian Air conditioner Market – source BSRIA 2005, JARN 2012-2013

Regarding the more recent three years of the review period, if we take a look on the Figure above, it is possible to notice a very interesting growth on sales over the year 2011. This remarkable increase on sales was influenced by an abnormally hot weather in summer 2010 when summer temperatures did not fall below 30-33 °C for one consecutive month, causing a subsequent growth on sales in the following year. The demand for air conditioners was several times higher than the commercially available stock. The demand could not be covered and by the spring of the following year the demand for air conditioners became a sort of panic.

The Russian market in 2011 was the 5th largest market in the World for windows, movables and splits.

Market for Windows was a quite important market in the early 2000s accounting around 25 % of the domestic air conditioning market in 2004 with 121,000 units sold in the year. In 2010 sales for Windows were around 40,000 units and in 2011 the demand reached 80,000 units, falling again to 45,000 units in 2012.

Movable units counted 9,000 units sold in 2004 and they have been continuously stealing market shares from Window units reaching 42,000 units in the year 2010. 2011 was for Movables a very positive year, 150,000 units were sold in the year and in 2012 the sales were just stable. It is a very popular solution for residential cooling, especially in the southern region of the country.

Splits since the first years of the review period has been the technology with highest share with 350,000 units sold in 2004. The market for splits has been increasing and in 2010 the sales reached 1,700,000 units sold. 3,100,000 units were reached in 2011 and in 2012 decreased again to 1,900,000 units. The heat wave was the leading motive of this incredible increase on sales.

Single-splits totally dominate the market in terms of numbers and values and more than 60 % of all sales were concentered in the Moscow region.

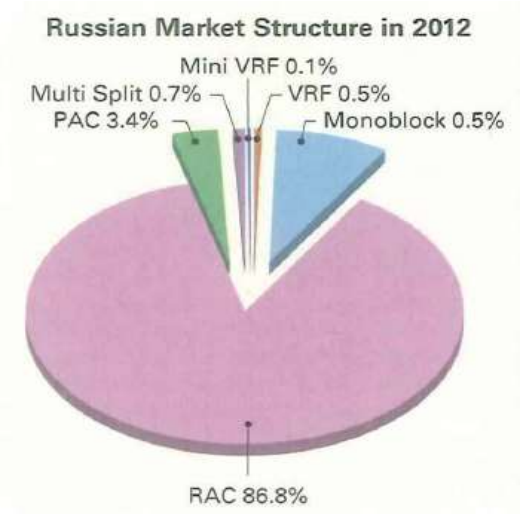


Figure 7.57: Russian Market Structure – source JARN May 25 2013

Indoor Packaged and Roof top units do not account a considerable market share, around 400 units for each technology.

The demand for chillers with a power < 100 kW reached around 1,200 units in 2011.

Sales for AHUs rose from 44,000 units in 2010 to 56,000 units in 2011 and the expectation is for a further growth in the following years. The demand is focused on multi-functional units, with heat recovery, humidification and integral control.

FCUs accounted 72,000 units in 2010 and the demand rose to 77,000 units in 2011 and they are mainly chosen for heating applications.

There are no significant data available for the Russian heat pump market.

7.8.3 The Russian Residential Construction Market

The total Russian housing stock area amounted to 3,177 million of m^2, 83 % of the total residential floor area is dedicated to single-family houses, and the rest of it to multi-family ones.

The average size of a single-family dwelling is around 60 m^2 and 45 m^2 is the average size of multi-family house.

The percentage of buildings constructed before 1995 exceeds 90 % and this percentage most of the dwellings were built before 1970.

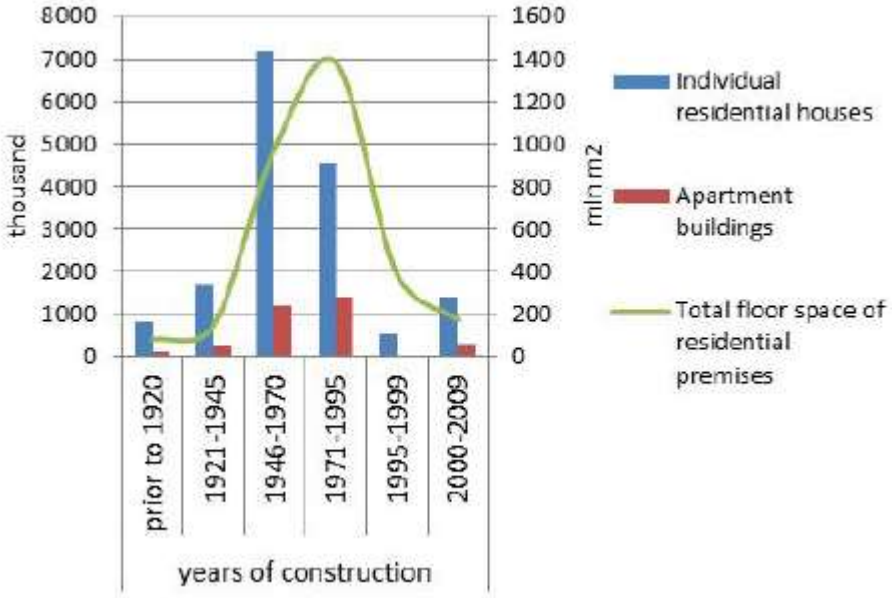


Figure 7.58: Distribution of buildings and residential area by year of construction – source Rosstat data

CIC study on the Russian construction reports the following data: in the review period (2009-2013) the Russian construction industry recorded a Compound Annual Growth Rate (CAGR) of 12.81 %, in 2013 valuating it US$ 252.9 billion.

Over the forecast period (2014-2018), the industry is expected to continue to grow and record in 2018 a value of US$ 331.6 billion a CAGR of 7.36 % over the forecast period.

The residential construction was the second largest market within the Russian construction industry in 2013, accounting the 23.8 % in value terms, the market was valued US$ 60.1 billion in the same year. Recording a CAGR of 13.30 % during the review period. During the forecast period the industry is expected to record a CAGR of 6.67% and to value US$ 76.3 billion in 2018.

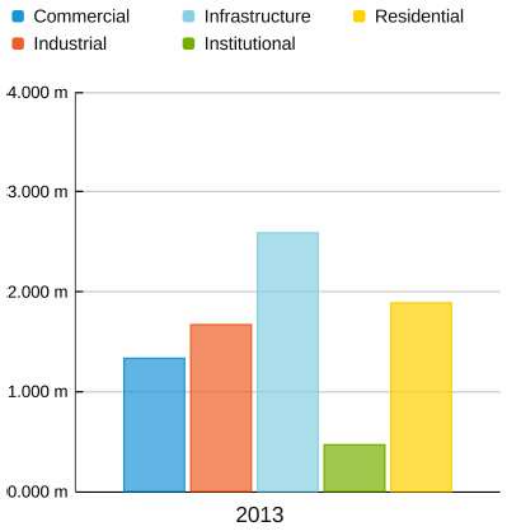


Figure 7.59: Russian Construction Market by Project Sector – source Construction IC

The growth of the residential construction market was supported by demographic and expanding population conditions.

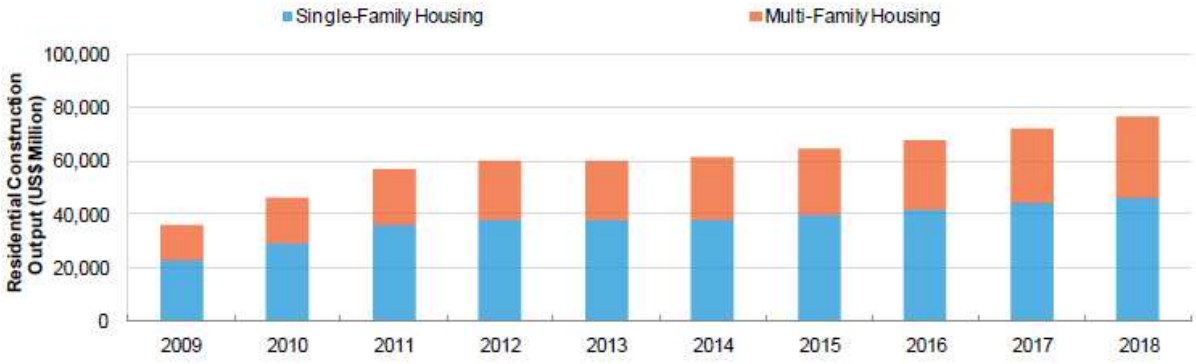


Figure 7.60: Russian Residential Construction Output by Project Type, 2009-2018 – source Construction-IC

Single-family housing was the largest category within the Russian residential construction industry during the review period, accounting 62.8 % of the total share in value terms. It was recorded a CAGR of 12.85 % during the review period and a value of US$ 37.7 billion in 2013.

The growing population and the increasing urbanization will be the main drivers for a growth over the forecast period. The category is expected to record a CAGR of 5.98 % and to value US$ 46.4 billion in 2018.

7.8.4 Considerations

The Russian climate is particularly rigid during most of the year. But not everybody know that, especially in Southern region of the country, summers are quite warm and humid.

Russia is the country with the highest percentage of natural resources within the World, in particular there is plenty of Natural Gas, which is also the principal energy source.

The air conditioning market has been having a notable growth during the review period, to reach record values during year 2011. And according to JARN perspectives look of a stability of the market around the 2012 values.

Heat pumps do not represent a promising technology in Russia, mainly because the principal energy source for the residential sector is Natural Gas and there are no incentive policies which have the target to change primary energy consumption from gas to electricity or policies for renewables.
The residential construction market seems to be very promising, and Single-family houses have had a big impact on the market and perspectives are of a continuing trend.

7.9 TURKEY

7.9.1 Introduction

The economic recession of the Eurozone in 2008 provoked a temporary slowdown on the Turkish economic growth. However, Turkey spared the economic decline, and not being part of the Eurozone helped on this.
The economy recovered from the crisis really well, in the two years 2010 and 2011 the GDP grow rate has been growing by 8.2% and 8.5% respectively. After those years the economy has been stabilizing to GDP values around 3%.

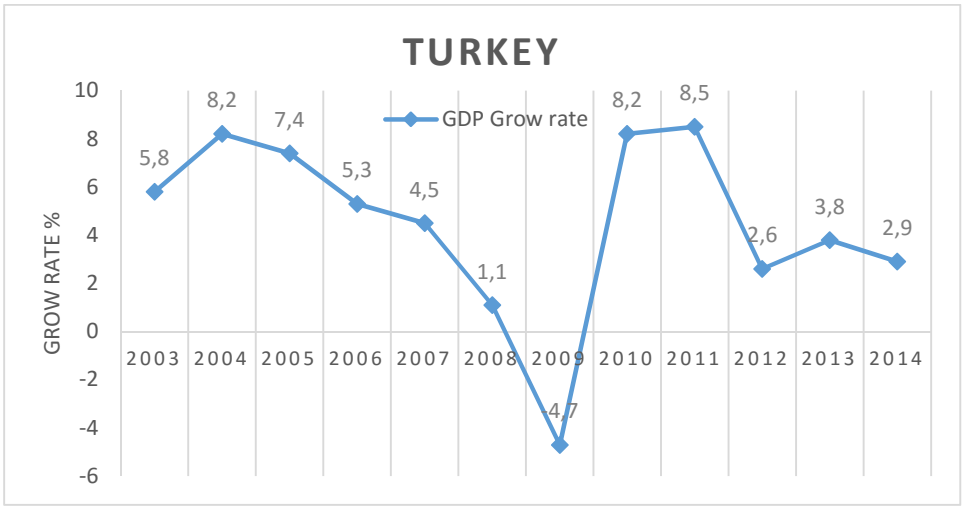


Figure 7.61: GDP Grow Rate in percentage, Turkey – source OECD

The Turkish climate is quite different among the country mainly because of the varied nature of the landscape and the presence of the mountains. The coastal areas, the Mediterranean and the Aegean, are characterized by cool winters and hot and dry summers. In the west summers are also hot and dry.
Whereas in the mountain area the climate is very rigid.
Around 25% of the total final energy consumption is dedicated to the residential sector.
Natural Gas and Electrical energy are the dominant sources in the final energy consumption of households. According to the Investment Support and Promotion Agency of Turkey (ISPAT), the country's demand for electricity is expected to increase in the next few years. The total power capacity is expected to increase.
The main target for Turkey is to become a very powerful economy by 2023 and the Turkish government allocated several economic resources to become the 10th fastest growing economy in the world by 2023.
The penetration of air conditioning in the residential sector was 30% in 2012 and 42% in the commercial one.

7.9.2 The Turkish Air Conditioner Market

The Turkish Air conditioning market has been increasing during all the review period, becoming the second biggest market in Europe. It was in 2003 an unsaturated market and the good economic situation has been favorable for the distribution of cooling systems. In the past, air conditioning was perceived as a luxury in Turkey, during the review years air conditioning constantly increased its penetration in the commercial and in the residential sectors and sine then it is considered as a standard item.

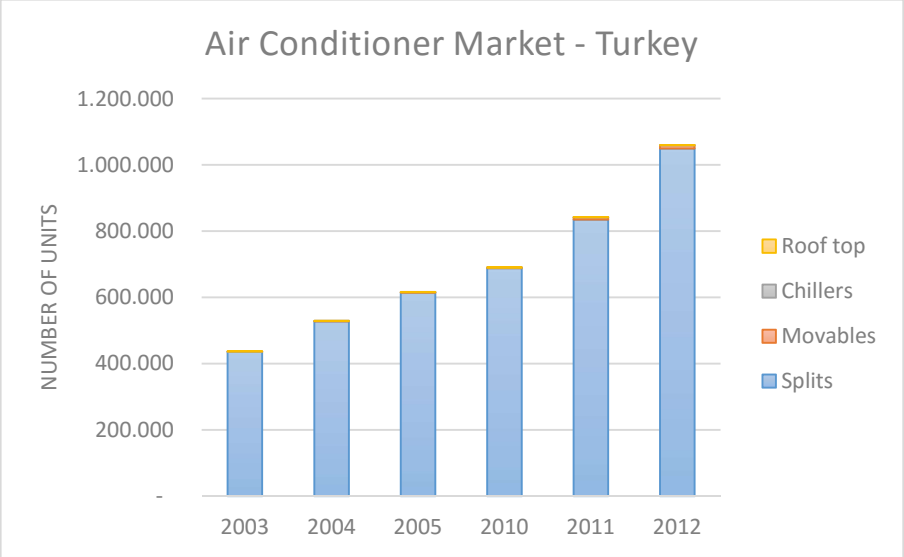


Figure 7.62: Turkish Air Conditioner Market – source BSRIA 2005, JARN 2012-2013

Windows since 2003 has been disappearing, and they are not even present in the Figure above.

Movables have been increasing their market in recent years, in 2003 accounted around 600 units, while the three latest review years, from 2010 with a base of 1,700 units rose to 6,600 units in 2011 and again an additional growth to 9,000 units sold in 2012.

Splits represent the dominant technology in the Turkish air conditioner market. In the two years 2003-2004 the split market increased by 30 % per year accounting 527,000 units sold in 2004, and the main typology sold in the years was the single-split one.

In the last three years of the review period splits increased considerably their sales 688,000 units were sold in 2010, in 2011 the sales rose to 835,000 units and in the last year of the review splits reached over one million units.

Single-splits continue to dominate the market with 95 % in term of numbers.

In Turkey the VRF market is also very dynamic, it accounts the 22 % of the market share in value terms and in 2012 the VRF market was estimated to 22,000 units. According to JARN the market is expected to continue to grow.

The Turkish market will be influenced by the European directive on energy efficiency, selling prices are expected to be increased by a 20 %. However prospects are very positive.

Indoor Packaged do not have a market in Turkey, roof tops accounts around 1,000 units and it is a stable market.

Market for chillers with a power <100 kW was around 600 units in the two years 2011-2012, it is mainly a market for the tertiary sector.

AHUs sales reached 8,000 units sold in 2011and the market is expected to increase a bit in the next few years. Most units are chosen in semi-custom configuration and the heat recovery model is becoming quite common.
FCUs have a very high market share, 106,000 units were sold in 2011 and in 2012 the market reached 113,000 units. It is the third European largest market after Italy and France.

7.9.3 The Turkish Residential Construction Market

The total building floor area in Turkey was in 2014 173.1 million of m^2. 70 % of the total floor area is dedicated to residential buildings. The 95 % of the total residential floor area is for multi-family dwellings and the rest 5 % for single-.family ones.

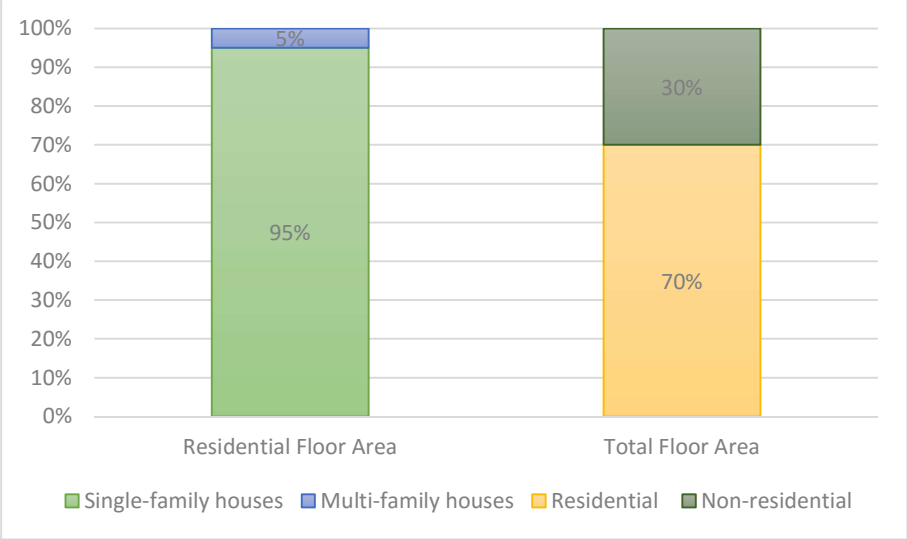


Figure 7.63: Building by type – source Turkish Statistical Institute

The Turkish construction industry was valued in 2013 US$ 83.7 billion, it has been performing during the review period (2009-2013) a CAGR of 12.6 %, the industry was supported by private and public investments in the various sectors. The value of the construction market was higher than the Greece but lower than the Italian, the German and the French.
The construction industry is expected to continue to grow over the forecast period (2014-2018), and perform a CAGR of 8.07 % and to value US$ 115.6 billion in 2018.
The residential sector represented in 2013 the 51.4 % of the total construction industry. It was the largest market over the review period, performing a CAGR of 11.82 % and valuing US$ 43 billion in 2013.
This very positive performance has been supported by a very high demand for housing, population and economic growth and urbanization.
The residential construction market is expected to record a CAGR of 7.63 % over the forecast period and to value in 2018 US$ 58.3 billion.
It is important to notice also that people in Turkey prefer to own houses rather than rent them. Also the population in Turkey for the 42.5 % is aged between 15-40 years, which is the most potential age for the residential sector. These have been the key drivers for the increase of the residential construction market.

Multi-family houses represented the 94.6 % of the total market share in 2013, the biggest residential construction category. During the review period, multi-family housing constituted also the fastest growing category, recording a CAGR of 12.07 %, and a value of US$ 40.7 billion in 2013.
During the forecast multi-family housing category is expected to record a CAGR of 7.67 %, and reach a value of US$ 55.2 billion.

Figure 7.64: Turkish residential Construction Output by Project Type – source Construction IC

Single-family housing accounts the remaining share, in 2013 represented the 5.4 %. Recording a CAGR of 7.91 % during the review period and value US$ 2.3 billion. The forecast is a CAGR of 6.87 % and reach a value of US$ 3.1 billion.

7.9.4 Considerations

Turkey represents one of the economies with the greatest potential in Europe. After being influenced by the financial crisis it has been reacting very well and being able to bring back its economy to appreciable levels.
The Turkish air conditioning market has been growing during the review period, constantly, until becoming nowadays the second biggest market in Europe and it is still growing.
The market is completely dominated by single splits. Movables are increasing their market share but they are a technology mainly chosen in particularly hot summers.
As in the case of Russia, heat pump is not a widespread technology, but maybe in the future, with an increase on the electric production could be a promising system.
The construction market marked very positive signs in the last few years, and prospects look like very positive.
In spite of this, the single-family housing share is very low considering the total residential floor area, therefore Turkey does not represent a potential market for single-family houses.

7.10 SWEDEN, FINLAND, NORWAY AND DENMARK

Despite the rigid climates typical of the Scandinavian Peninsula and of Denmark are not favorable for the spread of cooling systems, it is interesting to analyze the situation in these countries since in the near future N-ZEB buildings are becoming every year more common and the need for cooling in these buildings could be necessary. However, several experts think that there is no necessity to install in N-ZEBs active cooling systems although it is sufficient passive cooling systems, for instance a shading system or a system for the air exchange.

Nevertheless, the tendency of heating and cooling devices is of a complete and continuous control of all the comfort parameters in a dwelling and also Nordic countries could be potential markets.

I consider appropriate to know the trends of the heat pump markets and of the construction markets in these countries. The analysis will not be deepened as previous cases.

7.10.1 Sweden

Sweden has the biggest economy among Scandinavian countries and it has the one of the biggest GDP per capita in the world.

The financial crisis affected also Sweden but from 2010 onwards the recovery has been consistent.

Sweden is characterized by higher temperatures than similar countries with the same latitude, this is due to the fact that it has influences from the North Atlantic Ocean. However the climate is quite rigid, especially in Northern Sweden, while the Stockholm region has average temperatures in July around 18 °C.

In the Swedish residential and service sectors, electricity and district heating represent the dominant energy sources. Electricity accounts 48 % of the total consumption while district heating takes a 31 % share. Biofuels and oil represent the third and the fourth sources of energy, while Gas is marginal.

District heating dominate completely the heating sector of multi-family dwellings.

The Swedish construction market is expected to grow in the next few years, it is expected a CAGR of 4.8% during the forecast period (2014-2018).

The residential sector was the largest market in the Swedish construction industry in 2013 and the same percentage of the CAGR of the total construction market is expected for the forecast period.

Until 2010 the share of new multi-family dwellings in the residential market became higher than the single-family one.

Figure 7.62: Swedish Residential Construction Market by Project Type – source Construction IC

The Sweden heat pump market has become mature, the technology has reached full acknowledgment especially in the domestic sector.

According to the European Heat Pump Association (EHPA) more than one million of heat pumps were in operation in 2013. Nowadays this technology is the preferred choice in new construction applications but also for renovations of existing dwellings. More than 50 % of Swedish residential dwellings make use of heat pumps.

However the single-family housing sector is losing interest on heat pump technology, whereas the multi-family one is increasing attention.

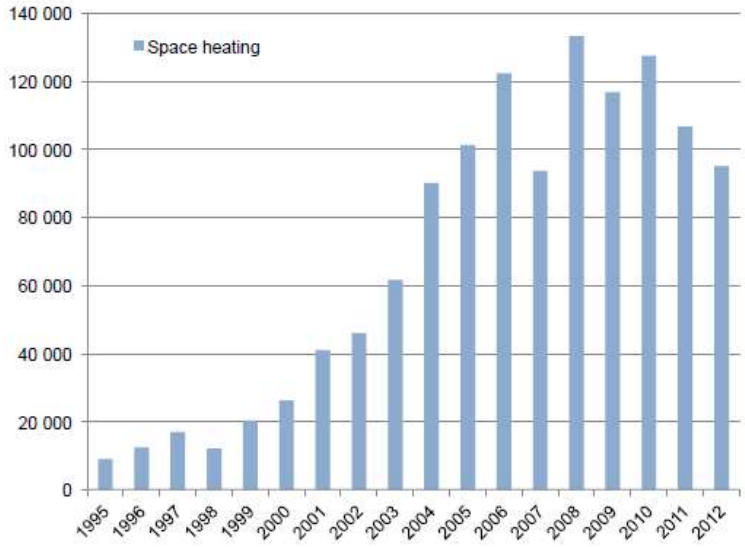


Figure 7.63: Swedish Heat Pump Market development 1995-2012 – source EHPA Market and statistics report

District heating dominate completely the multi-family heating sector and district heating companies are trying to limit the spread of heat pumps. However the prices for district heating have been increasing during recent years and it is a big opportunity for the heat pump technology.

Swedish energy policies were promoting the use of biomass for district heating and trying to limit the use of electricity for heating applications. But since then the subsidies coming from the policy ended and the price for biomass increased. A relevant number of pellet systems have been replaced during recent years with heat pumps.

In the review period (2009-2012) the total sales have been decreasing.

In particular Air/Water heat pumps declined by around 60 % in the four years 2009-2012.

Ground sourced heat pumps also decreased in sales and in 2012 declined by 22 % respect on the previous year.

Air/Air version with main heating function is the one with the biggest market share accounting around 100,000 units sold in 2012 and it is the predominant technology. A recent trend in Swedish residential dwellings is to install Air/Air heat pumps in holiday homes or as support for traditional heating systems and mainly are single-split systems applied in single-family dwellings.

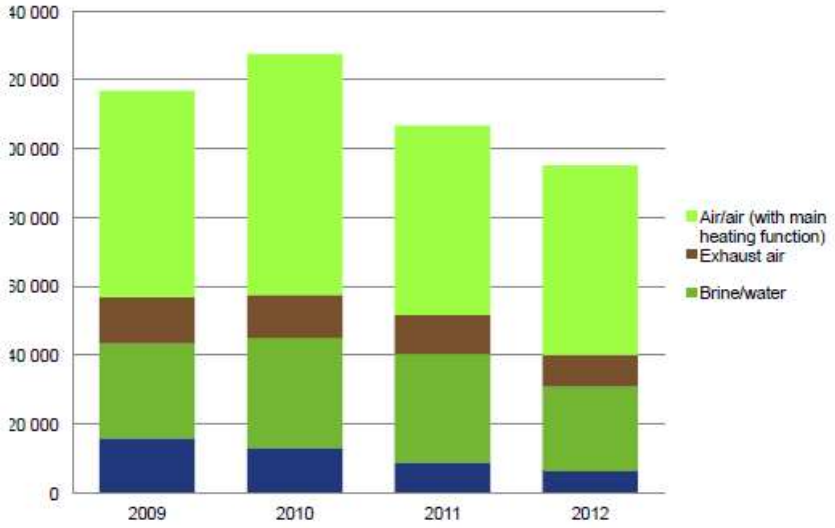


Figure 7.64: Swedish 2009-2012 heat pump market evolution by type - source EHPA Market and statistics report

Air/Water heat pumps are for climatic reasons more common in the southern Swedish region, and in the case of new buildings, due to regulations matters, they can only be applied in this part of the country.

MARKET TRENDS HEAT PUMP TECHNOLOGY

Heat Pump type	2009	2010	2011	2012	2011/2012 evolution
Air/Water	15,941	13,120	8,958	6,384	-29%
Water/Water				18	
Brine/Water	27,544	31,954	31,384	24,502	-22%
Exhaust Air	13,415	12,500	11,433	9,203	-20%
Air/Air (main heating function)	60,000	70,000	55,000	55,000	0%
Total	116,900	127,574	106,775	95,107	-11%

Table 7.6: Market trends for heat pump type 2009-2012 - source EHPA Market and statistics report

Ground sourced heat pumps have a considerable market share, and they are quite spread. The main reasons are the favorable conditions regarding drilling, and its reasonable costs.

7.10.2 Finland

As for Sweden, in Finland district heating and electricity are the main energy sources for the residential and building sectors. 42% of the total consumption is represented by electricity and the 31% by district heating.
Space heating accounts the largest share of energy consumption in residential dwellings with a 68% share, followed by water heating (11%).
District heating is mainly dedicated to multi-family dwellings with 88% share whereas electricity is the main source for heating single-family houses, 43% share. Gas heating is not present.
The total floor area of residential buildings in Finland is around 200 million of m^2. Are present around 2.5 million of residential dwellings and a bit more than half of them are single-family houses.
The average size of a single-family house is 97 m^2.
Owner occupants are dominant in residential buildings with 66% of the total stock, and the 97% of single-family houses.

The Finnish construction industry has been growing in recent years, recording a CAGR of 2.34% in the five years 2009-2013. It is expected to continue in its growth, in the forecast period 2014-2018, the industry is expected to record a CAGR of 1.5%.

The residential construction industry will follow this trend and it is expected to perform a CAGR of 1.19% in the forecast period.

The residential construction market was the biggest in the industry in 2013. Single-family housing with a 62.2% share in 2013 was the largest category in the residential industry. It is expect to perform a CAGR of 1.42% in the next four years.

Figure 7.65: Finnish Residential Construction Market by Project Type – source Construction IC

The Finnish heat pump market for the domestic sector accounted in 2012 around 60,000 units sold. The market in 2009 accounted 80,000 units.

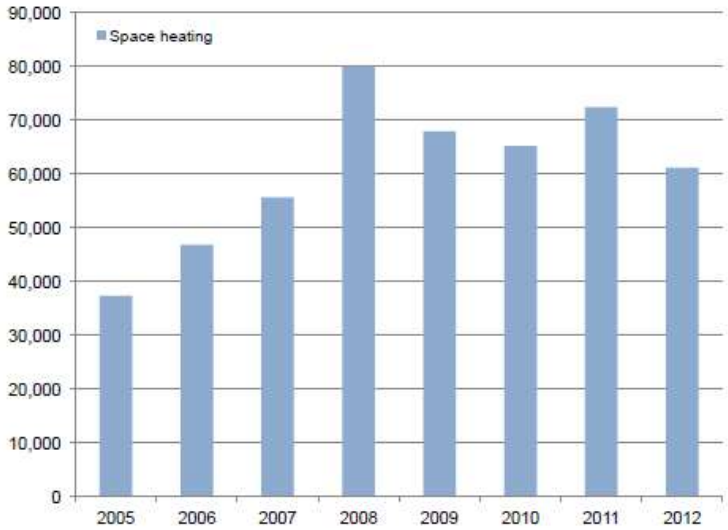


Figure 7.66: Finnish Heat Pump Market development 1995-2012 – source EHPA Market and statistics report

The heat pump technology is becoming well known, around 540,000 heat pumps were in function in Finland in 2012 and it is considered the best choice for new construction especially single-family house applications and also for renovations. According to the EHPA, heat pumps are almost in 30% of Finnish single-family houses and the penetration in new houses is around 50%. The penetration in single-family houses is destined to increase also because several dwellings still have oil based heating system or still use hydronic-electric heating system.

The incentive program introduced for renovation in Finland will support the spread of heat pump technology.

MARKET TRENDS HEAT PUMP TECHNOLOGY					
Heat Pump type	2009	2010	2011	2012	2011/2012 evolution
Air/Water	1,819	1,150	992	979	-1.3%
Brine/Water	6,137	8,091	13,941	12,953	-7.1%
Exhaust Air/Air	1,819	1,988	2,084	1,912	-6.6%
Air/Air (main heating function)	57,977	53,821	55,286	44,956	-18.0%
Total	67,752	65,050	72,267	61,006	-15.6%

Table 7.67: Market trends for heat pump type 2009-2012 – source EHPA Market and statistics report

In the last year of the review period all the different typologies of heat pumps suffered a decrease on the sales, especially the Air/Air version which declined its market share by 18% compared to the previous year.
Air/Air is the most widespread heat pump typology.

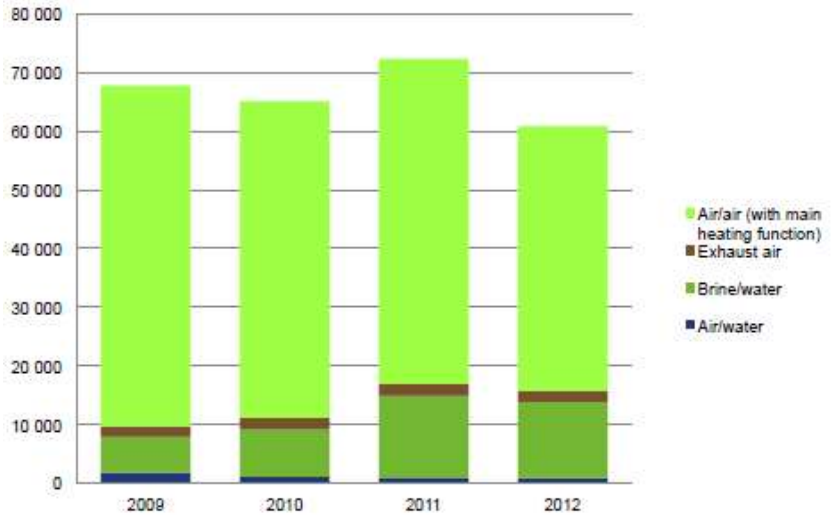


Figure 7.68: Finnish 2009-2012 heat pump market evolution by type - source EHPA Market and statistics report

7.10.3 Norway

The Norwegian has been a growing economy since the 90s, and after a small period of recession in 2009 continued its growth.
Electricity represents half of the end energy use in Norway, and it is the main energy source and in household it accounts around 80% share in 2010. Biomass is the second with a 16% share.
The heating share of the total consumption in households was calculated recently from estimations and it accounted approximately 66% in 2010.
Electric heating systems are used in about 70% of dwellings, as unique systems or even in combination with other types. While hydronic heating systems is around 12%, and also a large share of residential dwellings use hydronic systems electrically driven.
The Norwegian total residential dwelling stock accounted in 2005 around 2.2 million of dwellings. 57% of the stock was composed by single-family dwellings and rest 43 % by multi-family houses.
The Norwegian construction industry has been growing in recent years, reporting a CAGR of 7.17 % over the review period (2010-2014) and the residential construction market was the largest in the industry in 2014

accounting a 44.4% share and a value of US$ 34 billion. It was also the fastest growing market with a CAGR of 13.89 % over the review period. The market is expected record a CAGR of 5.68% over the forecast period (2015-2019).

In Norway the heat pump is a well-known technology since the 80s, when the government supported a program for the spread of heat pumps, mainly in the commercial the industry sectors.

The first energy source for heating of residential dwellings is electricity, however not so many private houses have installed heat pumps until 2000s.

During recent years, most houses have installed heat pumps as low temperature heat source and more than 30% of single-family houses have heat pumps.

It is interesting to notice that according to the EHPA, most of residential dwellings in Norway do not have a hydronic heat distribution system and for this reason the most spread typology of heat pump is the Air/Air version. In 2012, around 90% of the total heat pump sales were Air/Air heat pumps, 61,050 Air/Air heat pumps were sold in the year.

MARKET TRENDS HEAT PUMP TECHNOLOGY

Heat Pump type	2009	2010	2011	2012	2011/2012 evolution
Air/Water	4,154	3,530	2,914	2,806	-3.7%
Brine/Water	3,532	2,863	3,677	3,211	-12.7%
Air/Air (main heating function)	75,626	87,222	76,394	60,959	-20.2%
Exhaust Air/Air	724	227	473	316	-33.2%
Total	84,036	93,842	83,458	67,383	-19.3%

Table 7.7: Market trends for heat pump type 2009-2012 – source EHPA Market and statistics report

Smaller markets are represented by the Air/Water one with 2,806 units sold in 2012 and with 3,211 units the Brine/Water models. There is also a small market for VRF heat pumps.

The whole heat pump market lost in the two years 2011-2012 around 20% of the market but still it represents a promising market, in the future is expected a higher penetration.

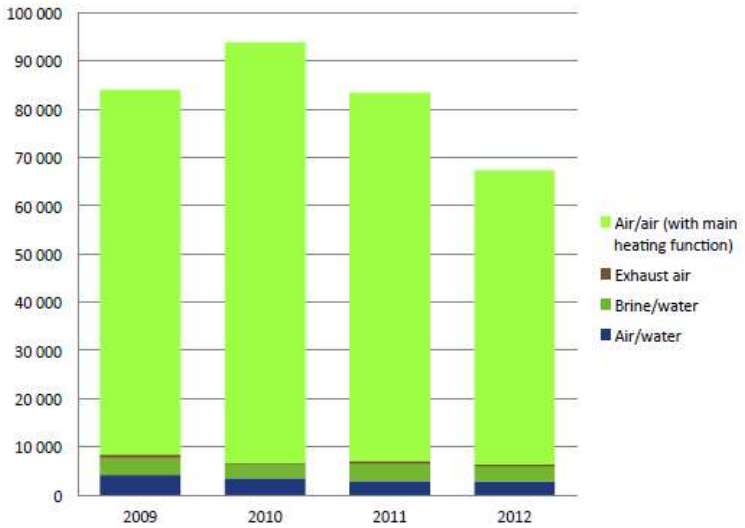


Figure 7.69: Norwegian 2009-2012 heat pump market evolution by type - source EHPA Market and statistics report

The Norwegian public company Enova for the support of renewable energies and energy efficiency, has introduced an incentive program for private householders who have a hydronic based distribution system, for the installation of ground-sourced heat pumps and Air/Water heat pumps, a subsidy of 1,100 € and if it is substituted an oil burner the subsidy becomes 3,000 €.
The Air/Air heat pump do not receive any subsidy.

7.10.4 Denmark

District heating is the main energy source in the residential sector in Denmark, 61% of the total households are supplied with district heating, 15% are connected to the gas grid, and 14% make use of oil boilers and 9% use electricity or other energy sources.
Government policies have the target of reducing the use of oil and gas-fired boilers in new buildings from 2013 and also oil-fired boilers in district where district heating is available are banned from 2016. Most of dwellings with oil fire burners are usually matched with hydronic systems, owners are expected to change their burner with Air/Water heat pumps or with Ground sourced heat pumps.

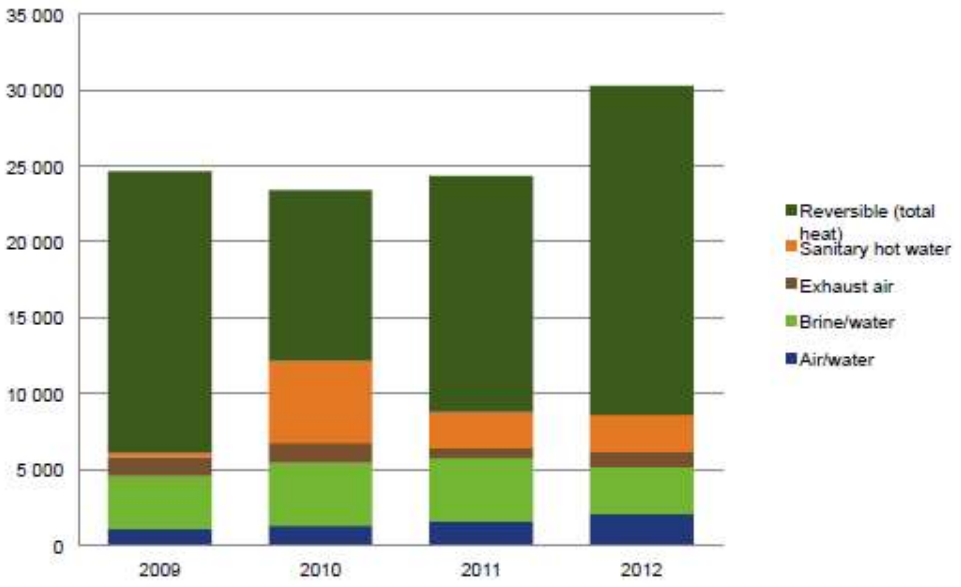


Figure 7.70: Danish 2009-2012 heat pump market evolution by type - source EHPA Market and statistics report

The heat pump market has been stable for the first three years of the review period, and in the last year between 2011 and 2012 increased by 23 %.

MARKET TRENDS HEAT PUMP TECHNOLOGY

Heat Pump type	2009	2010	2011	2012	2011/2012 evolution
Air/Water	1,123	1,325	1,597	2,113	32.3%
Brine/Water	3,475	4,137	4,172	3,072	-26.4%
Exhaust Air/Air	1,246	1,292	658	997	49.5%
Sanitary Hot Water	273	5,430	2,386	2,457	3.0%
Air/Air (main heating function)	18,540	11,240	15,513	21,635	39.5%
Total	24,069	23,160	24,634	30,393	23.3%

Table 7.8: Market trends for heat pump type 2009-2012 – source EHPA Market and statistics report

Air/Air heat pumps represent the biggest share accounting around 21,000 units in 2012.
All the other segments are also growing except for the brine water one which decreased by 26% over the last two years of the review period accounting in 2012 3,072 units sold in 2012.
The current incentive program encourage the spread of electricity as primary heating source with reductions on electric prices.
Heat pumps as electrically driven renewable sources are considered a very interesting solution on a Smart Grid evolution. According to the EHPA 480 homes received intelligent control and demand side regulation systems, and also around 100 have heat pumps integrated in an advanced market design with variable electricity prices.

8. CONCLUSIONS

In the study were analyzed two categories in which can be observed trends. The first is related to a technological analysis, while the second one concerns a market analysis, more precisely the Air Conditioning, the Heat Pump and the construction markets were examined.
After having observed the two categories separately and highlighted the trends, it is interesting to combine the conclusions in order to have an overview on those that are the trends of application cooling in single-family houses.

The technological analysis has revealed the main characteristics of the various systems, the strengths and the weaknesses. Furthermore it has showed which may be in the future the technological evolutions.
In the study were taken into account systems which have cooling as main function and regarding them we refer to split systems which are the most common systems in the air conditioning market. Their technological evolution has been and will be deeply influenced by research of a refrigerant fluid at a lower environmental impact, good alternatives are already available and first new products are stepping into the market.
Internal units of split systems are becoming every day more and more aesthetically integrated into a domestic environment. Furthermore it should be emphasized that all split systems available on the market are in heat pump version and they can easily satisfy cooling and heating needs.
Alternatively, for those system which are generally known as heating systems but can also have cooling function, as for instance radiant systems, all-air systems or fan coils. These systems are rarely chosen with the only cooling function in the residential sector. They are more onerous solutions compared to split systems and their cost becomes sustainable when the function of the system is not limited to cooling but is extended also at the heating application. Furthermore the cost of these systems also depends on the cost of the energy source, the heat pump or the chiller. A trend that they all have in common is the development of systems towards products which are able to provide heating and cooling needs, all as a unique and compact solution, seeking higher comfort levels. This development is part of an overarching trend towards the provision of a comfortable living environment in increasingly energy efficient houses.

Regarding the air conditioning market analysis it has been observed that are only considered those technologies which have cooling as main function. The results show that all the southern European markets as the Spanish, the Greek, and the Italian ones, they have been decreasing and they are affected by a deep crisis mainly driven by the financial situation. They do not appear in recovery.
Central Europe's markets, the French, the German and the British seem to have room for growth.
Whereas northern European countries are not even mentioned in the analysis except for the Russian market which is the biggest one in Europe.
Split systems is the leading technology in all the countries counting around 90% of the total market share in terms of numbers, and there are no other technologies capable to compete with them.

From the heat pump market emerged which are the potentialities of the systems which have heating as main function but also what impact may have Air/Air heat pumps (Splits) as heating applications.
For instance in Southern Europe Air/Air heat pumps are the most widespread and they are slowly spreading as a cooling and heating application.

The central European market is the biggest for Air/Water heat pumps, especially the German and the French. Hydronic systems are expected to have a very strong impact on newly built single-family houses.
Air/Air heat pumps with main heating function are also in northern Europe, Sweden, Finland, Norway and Denmark the most common heat pump configuration.

The construction market provided indications on which will be the most interesting construction industries in the next few years. The French residential construction market is the biggest in Europe and it will count also a quite big share of newly built single family houses. The German market together with the British one are considered to be the most interesting ones from a growing point of view. The German residential construction industry will be driven by refurbishment and repair and maintenance sectors. While investments in the British residential construction industry will be addressed to new single-family houses.
The Italian market is expected to recover in the next few years after past years of crisis, but still it has been one of the biggest construction industry in Europe.

Inspired by technological and market trends it is interesting to observe more in general which the tendencies among the different zones in Europe are.
There were noted similarities between States, more specifically it is possible to subdivide in three climatic zones Europe: South, Center and North.
Southern Europe, represented by Spain, Greece and Italy, is characterized by a very warm climate. In this area split systems have been and also will be the leading technology in the air conditioning market, despite the crisis, and also because no significant data for chillers or Air/Water Heat Pumps justify a different perspectives, in the next years for both newly built and existing single-family houses.
Furthermore, according to the EHPA report, Air/Air heat pumps (splits) with both heating and cooling functions will be chosen not only as a cooling system, but also as a heating system in very warm regions, in which the heating season is very short and temperate, as southern Spain, Greece and also Southern Italy. In the other southern regions split units will be utilized as additional cooling systems to the already present heating system.
France, Germany and UK which represent the Central area, are stable markets and in existing single-family dwellings where is already present a heating system, even in this case split units will be chosen as cooling systems. In refurbishments and renovations of heating systems, technologies for both heating and cooling applications which are more suitable to substitute the replaced system could have an interesting impact.
In newly built single-family houses, where can be installed new heating systems but which can also provide at cooling, in this case those systems dual function systems as radiant systems or fan coils could be the optimal solution.
The growing trend towards Air/Water heat pumps in France and Germany, it is an additional indication of how hydronic systems could satisfy heating and cooling needs.
The spread of photovoltaic systems in single family dwellings could also push electric driven heat pumps towards an increasingly higher diffusion.
Northern countries, with the exception of Russia, present a different situation: in Sweden, Finland, Norway and Denmark there is not a real need for cooling, summer temperatures do not justify purchases of systems dedicated at cooling. However, exceptional temperatures that have strongly influenced the market in 2011 in Russia, and

which have led to an incredible increase on sales, may occur in those countries and lead to similar consequences of Russia.

Nevertheless, in Northern countries are already very spread technologies as NEST or other independent environmental control systems and even though there is not a primary necessity for cooling, systems which are able to vary dynamically all comfort parameters could be very interesting solutions in future perspectives.

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