Bricker project: Power, Heating and Cooling for Public Non-Residential Buildings Feeding with RES

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Abstract

Existing non-residential buildings represent a valuable asset in Europe. These buildings account for 25% of the total building stock in Europe and comprise a more complex and heterogeneous sector compared to the residential one. The public non-residential building stock represents an average 31% of the total non-residential sector in Europe. Understanding the energy use and CO_2 emissions in the non-residential sector is complex as end-uses such as lighting, ventilation, heating, cooling, refrigeration, IT equipment and appliances vary greatly from one building category to another within this sector. The average specific energy consumption in the non-residential EU27 sector is 280kWh/m^2 (covering all end-uses). A retrofitting solution package for existing public-owned non-residential buildings is needed in order to achieve a drastic reduction of the energy consumption (beyond 50%) and GHG emissions in this sector. This retrofitting package is based on; Envelope retrofitting solutions for demand reduction through made-to-measure façades, innovative insulation materials and high performance windows and zero emissions energy production technologies based on a cogeneration system fed with locally available and clean renewable sources. The retrofitting solution package is implemented in three real demonstration multi-buildings complexes, located in different climate conditions in three different European Countries and with different end-uses: Sanitary, Educational and Administrative.

Keywords: Energy efficiency, Renewable energies, Tri-generation, Zero energy buildings

1. Introduction

Existing non-residential buildings represent a valuable asset in Europe. These buildings account for 25% of the total building stock in Europe and comprise a more complex and heterogeneous sector compared to the residential one. The retail and wholesale buildings comprise the largest portion of the non-residential stock, while office buildings are the second biggest category with a floor space corresponding to one quarter of the total floor space. Understanding the energy use and CO2 emissions in the non-residential sector is complex as end-uses such as lighting, ventilation, heating, cooling, refrigeration, IT equipment and appliances vary greatly from one building category to another within this sector. The average specific energy consumption in the non-residential EU27 sector is 280kWh/m^2 (covering all end-uses).

Over the last 20 years in Europe, electricity consumption in European non-residential buildings has increased by a remarkable 74%. This is compatible with technological advances over the decades where an increasing penetration of IT equipment, air conditioning systems etc. means that electricity demands within this sector is on a continuously increasing trajectory. Buildings vary remarkably in terms of size where large variations are expected in the non-residential categories.

The ownership profile in the non-residential sector is heterogeneous. Private ownership can span from as low as 20% to 90% from country to country and also from one building type to another. The public non-residential building stock represents an average 31% of the total non-residential sector in Europe (Based on the survey “Europe´s buildings under the microscope” by BPIE in 2011.).

On the other hand, the heating and cooling of buildings take a large share in the energy consumption. The average energy consumption in the non-residential sector, such as public and industrial buildings, is estimated to be at least 40% greater than in the residential sector in Europe. Some reasons for this general increase are for example an increase in comfort habits, currently still low energy costs, architectural trends (glazed areas in

doi:10.18086/swc.2017.12.12 Available at http://proceedings.ises.org

buildings) and slowly changing in climate conditions. This rising demand for cooling and air-conditioning in buildings involves unfavourable fossil fuel consumptions as well as upcoming stability problems in the electricity supply in Mediterranean countries, which in turn demands for costly upgrading of the grids to handle electricity peak power demand situations.

Therefore, integrating technologies to make existing buildings more energy efficient is the challenge that the EU-funded BRICKER research project is addressing. The project consists of retrofitting showcase public buildings in Spain, Turkey and Belgium to achieve at least 50% reduction in energy consumptions compared to the values before renovation.

2. Demonstration buildings

The demonstration buildings are in use and the goal is to demonstrate the performance of the technologies and systems developed within the project. BRICKER combines various active and passive technologies to achieve energy efficiency in innovative ways. (In this case a tri-generation system capable of providing power, heating and cooling simultaneously). The system's activation heat will be produced using parabolic solar collectors working on a high temperature and biomass boilers adapted to the specificities of each demo site and its surroundings.

The demonstration buildings of this project BRICKER are 3, and are located in the geographical areas trying to cover the diversity of Europe. These buildings can be seen in Fig. 1 and are concretely located in Caceres (Spain), Liege (Belgium) and Aydin (Turkey). The idea behind the project is to demonstrate the operation of the technologies and systems developed and to achieve energy savings of more than 50% compared to the initial values prior to renewal. The investment costs associated are expected to be at most 20% of the total costs of a building compared to those due to a new one located on the same site, and return of investment around 7 years. All this can be seen reflected for each concrete case of each demonstration building below.

Fig. 1: Location of demonstration buildings in the BRICKER project

2.1. Demonstration building in Caceres:

Fig. 2: Administrative offices in Caceres

- Building: Administrative offices of the Government of Extremadura.
- Renovation: 1 administrative building of a set of 7 buildings.
- Useful area: 8,480 m^2.
- Occupation: 300 workers.
- Electrical savings: 60%.
- Return of investment: 7 years.
- Associated investment cost: 13.4%.

2.2. Demonstration building in Liege:

Fig. 3: School of Engineering in Liege

- Building: School of Engineering of the University of Liege.
- Renovation: 2 blocks of an academic complex formed by 7 buildings.
- Useful area: 23,000 m^2.
- Occupation: 1,200 students.
- Electrical savings: 86%.
- Gas savings: 75%.
- Return of investment: 7.2 years.
- Associated investment cost: 9%.

2.3. Demonstration building in Aydin:

Fig. 4: AHU Hospital in Aydin

- Building: AHU Hospital; Adnan Menderes University.
- Renovation: 1 building of the university hospital complex composed by 4 blocks.
- Useful area: 19,467 m^2.
- Occupation: 600 patients y 450 workers.
- Energy savings: 51%.
- Return of investment: 7 years.
- Associated investment cost: 10%.

3. Core of BRICKER project

Tri-generation concept or CCHP (Combined Cooling, Heating and Power) is the simultaneous production of mechanical power, heating and/or cooling from one primary fuel by coupling with thermally activated cooling technologies that take the waste heat from CHP for producing cooling.

Thermally activated cooling utilized for CCHP systems primarily refers to sorption refrigeration; it employs waste heat produced in the process of power generation as the driving force to power a sorption refrigeration device. Some energy demand for refrigeration is thus shifted from electrical to thermal energy, and primary energy consumption is also reduced. Another difference between sorption systems and conventional vapour compression systems is the working fluid used. Most vapour compression systems commonly use chlorofluorocarbon refrigerants (CFCs), because of their thermo-physical properties. It is through the restricted use of CFCs, due to depletion of the ozone layer that will make sorption systems more prominent. However, although sorption systems seem to provide many advantages, vapour compression systems still dominate all market sectors. In order to promote the use of sorption systems, further development is required to improve their performance and reduce cost.

Power generation system is an Organic Rankine Cycle (ORC) whose operation principle is the same as the conventional Rankine cycle, but in this case, the working fluid is an organic compound of low boiling point instead of water, thus decreasing the temperature needed for evaporation. A pump pressurizes the liquid fluid, which is injected into an evaporator (heat source) to produce a vapour that is expanded in a turbine connected to a generator. Finally, the output vapour is condensed and sucked up by the pump to start the new cycle. ORC heat source could come from renewable sources (solar, biomass, geothermal…), the ORC unit is able to produce electricity (DC) for self-consumption or for the grid, and another heat source at lower temperature (from the condensation side) than can be used for heating. If the heat source from the condensation is also used for cooling (using a sorption machine), we have a tri-generation system.

Most of the commercial installations of concentrating solar collectors are for large scale solar power generation in steam turbines. Large collectors and systems with high operating temperatures are targeted for optimal steam cycle efficiency. However, Parabolic Trough Collectors (PTCs) are also suitable for the medium temperature and medium size applications and for industrial process heat, desalination, solar air conditioning and distributed power generation with Cogeneration turbines or internal combustion engines. For state of the art, we refer to small (roof mountable) parabolic trough collectors commercially available today, because the larger parabolic trough can simply not be used on rooftops. These small parabolic troughs are optimized for the temperature range 100-200°C. This temperature range has a very large potential for industrial process heat and solar cooling. For small power plants where ORC and solar are combined, the temperature range should be increased up to the temperature range 250 to 300°C, i.e. at least 50°C above the current optimization range. Therefore, in the framework of the BRICKER project, the development, testing and integration of a parabolic through collector and whole solar fields to feed the cogeneration unit that works with a heat source of 250 +/- 30ºC, is also developed.

Several factors such as the heat sources available, the existing conventional systems and the new energy systems to be installed in the buildings within this project, the economic restrictions and the cooling and heating needs among others has been studied and has allowed to identify which of the solutions/configurations fitted better within the BRICKER concept. As has been mentioned before the main objective of BRICKER is the installation of a tri-generation system to provide energy in an optimal way to the building, so for that and following the original concept of a tri-generation system, the unique option is limited to use the residual energies coming from the BRICKER energy system to produce in this case cooling, and in this particular case has been concluded that the only option available is the utilization of the residual heat coming from the ORC in form of water condensation to feed the chiller unit as primary heat source. This limitation together with the need to produce chilled water at certain range of temperatures to feed the terminal units already installed has reduced the possibilities to only two, which are the installation of an adsorption chiller unit (Fig. 5) or on the other hand the installation of a single effect absorption chiller unit (Fig. 6). These two possibilities can be seen in the pictures below.

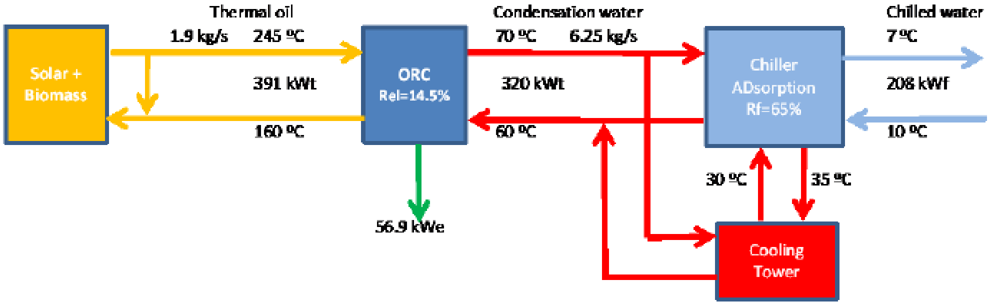

Fig. 5: Integration of an adsorption chiller

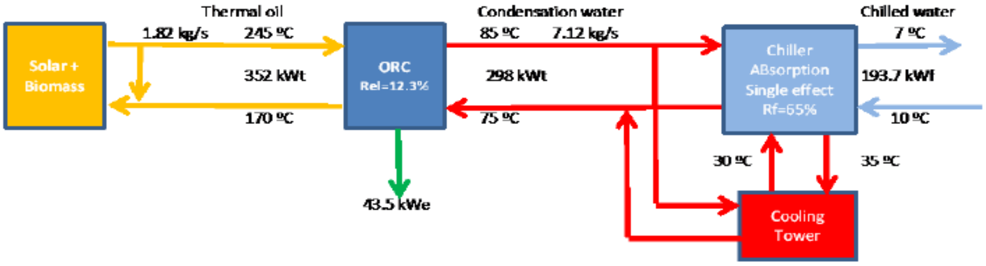

Fig. 6: Integration of an absorption chiller

The difference between them is mainly the activation requirements but also the working principle as one is using a liquid as sorption material and the other is using a solid.

Demo cases analyzed are two public buildings located in Spain (Caceres) and Turkey (Aydin). The first one is an administrative building of around 8,150 m^2 while the second one is a big hospital with a surface of more than 50,000 m^2. Due to their similar weather conditions (both located in the south of Europe) with hot summer periods, but also in the case of the hospital due to their specific conditions with cooling needs during the whole year, it is assumed the necessity of systems which provide the buildings with cooling capacity. In both cases original cooling systems are based on conventional heat pump systems which consume high amounts of electricity. So the idea is with the implementation of thermally activated cooling technologies within the BRICKER system to cover cooling needs of the buildings with the corresponding reduction of electricity consumption due to the less use of the conventional systems.

Many options are available and have been studied in terms of thermally activated cooling technologies, each of them with their own characteristics and limitations. After analyzing the different options and taking into account the boundary conditions imposed by each demo case has been concluded that the most suitable option is to install an adsorption chiller unit for both buildings. This selection has been due to the necessity to meet the original concept of tri-generation, in which is needed to make use of the residual energies coming in this specific project from the ORC water condensation at low temperature (70 ºC in cogeneration mode) as primary heat source. This limitation of temperature together with the possibility to get higher electrical performances in the ORC in comparison with the other thermally activated technologies (lower temperatures in the condensation side, makes the ORC to work with higher electrical performances), makes this selection as the most suitable. Other options such as the open cycle systems have been discarded due to the necessity to feed the terminal units at a given temperature (10 - 15 ºC). In the same way, the absorption units have been discarded due the operating limitations to work below 80 ºC in which the ORC develops their full potential in cogeneration mode. In addition, these machines have lower performances at working temperatures in the range between 80 - 90 ºC.

Although the selected technology has been the same for both demo cases (an adsorption chiller unit), it could be noticed that each has their own peculiarities. In the case of the Spanish demo case, the chiller unit has been dimensioned with the idea to cover all the cooling needs of the building, accomplishing the project economical restriction (only requiring additional support during occasional peak loads through a conventional heat pump system). In the Turkish demo case, due to their higher demand in terms of cooling, the idea is to cover only a little portion of it, so the selection is only based on the restrictions coming from the ORC (thermal energy limitations) and the economical ones.

4. Conclusions

Finally, two main conclusions can be drawn:

1. Energy use in public non-residential buildings represents a high proportion of the EU energy consumption and CO_2 emissions for the non-residential sector. In particular, hospitals, offices and educational buildings represent the highest levels of energy intensities of public-owned buildings.

2. Concerning the energy retrofitting solutions to be proposed for this target group, aiming at achieving nearly zero energy buildings, the scope must be related to systemic and integrated approaches involving:

a. Energy demand reduction by envelope optimization techniques (to decrease electrical and gas dependence).

b. Development and integration of Combined heat and Power (renewable based) solutions to produce both distributed heat and electricity at building and district level, according to the locally available resources.

c. Integration and optimization of the systems and its operation in cost effective way for the life cycle.

To sum up, the heart of this project is the development of innovative Combined Heating, Cooling and Power (CHCP) systems tailored to the specific needs of each demo building combining and adapting in the best way different subsystems (ORC units, parabolic through collectors, biomass boilers, sorption units) and locally available renewable sources (solar and/or biomass) as an example of high efficiency and renewable energy alternative, suitable for those buildings and districts with relevant electricity, heating and/or cooling needs.

5. References

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