MILANO GYMNASIA PROJECT: SOLAR VENTILATION SYSTEMS FOR SPORTING CENTRES AND MONITORING RESULTS

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1 DESCRIPTION OF THE SITE

The demonstration project consisted in public interventions concerning the sporting areas of two school centres owned by the District of Milano (in the north of Italy) and built around the 1980s.
The school centres are located in two little towns near Milano: Cernusco sul Naviglio and Pioltello.
The energy retrofit projects interested the gymnasia of the two school centres.

1.1 Cernusco sul Naviglio school centre

The retrofit intervention interested the sporting area of the school centre of Cernusco sul Naviglio, consisting in building blocks realised in different periods between 1979 and 1983.
In the school centre are located two gymnasium areas.
Global heated volume of the whole school centre is 64.351 m^3 with a covered surface of 6.376 m^2.
The intervention interested the two gymnasia.

1.2 Pioltello school centre

The retrofit intervention interested the sporting area of the school centre of Pioltello, consisting in building blocks realised in 1980 years.
Global heated volume of the whole school centre is 32.500 m^3 with a covered surface of 6.715 m^2.
The intervention interested the gymnasium.

2 DESCRIPTION OF THE INSTALLATION

The two public school centres were object of maintenance actions in order to reduce heat loss and energy consumption.
The innovative interventions were:
On the south facades of the gymnasia were installed air solar collector systems to preheat external air for space heating and ventilation.
Solar energy was also used for electricity production by means of Photovoltaic systems: electricity produced by the photovoltaic modules is discharged to the internal electric grid in order to reduce the electricity consumption measured on the general energy meter.
In Cernusco sul Naviglio school centre a hybrid photovoltaic/heating Solarwall system has been realised according to an innovative system already tested in Canada.
In Pioltello school centre a traditional PV system was installed.
An energy management system (EMS) controls the solar heating system identifying the best working condition with reference to internal and external

temperature. The PV system is also controlled by the EMS. The EMS also registers energy consumption data and monitors the energy saving results.

2.1 Solarwall System

Vertical solar facades on the buildings south walls have been realised consisting in large dark solar collectors placed on the south facade of the gymnasia.
Air solar collectors are used to preheat the external air that is introduced in the internal rooms and they are integrated with an air system for the space heating and ventilation.
Air solar collectors are used with high temperature and low air delivery in order to provide heat to the internal spaces covering part of the heat demand for space heating.
The external air is preheated by a corrugated aluminium sheet with small circular holes that allow air to flow into a cavity between the metallic surface and the wall of the buildings where air is preheated.
A by-pass dumper with thermostastic functions, permits the regulation of the fan operation that introduces external air in the buildings only when the final air temperature is 20°C or higher.
Internal air distribution has been realised at the roof level by means of horizontal pipes systems provided with small holes for the air distribution in the internal space.
Exhaust air is extracted at the roof level by the existing openings.

2.1.1 Cernusco sul Naviglio

In the school centre are located two gymnasium areas and two Solarwall systems have been installed.

Gymnasium n. 1	
“Solarwall” surface	190 m²
Exposition	South
Inclination	Vertical
Solarwall air flow	8.200 m³/h
Internal temperature	20°C
Heating season	6 months/year
Weekly operation time	6 days
Daily operation time	10 hours

Gymnasium n. 2	
“Solarwall” surface	140 m²
Exposition	South
Inclination	Vertical
Solarwall air flow	4.800 m³/h
Internal temperature	20°C
Heating season	6 months/year
Weekly operation time	6 days
Daily operation time	10 hours

2.1.2 Pioltello

Gymnasiun	
"Solarwall" surface	137 m²
Exposition	South
Inclination	Vertical
Solarwall air flow	8.000 m³/h
Internal temperature	20°C
Heating season	6 months/year
Weekly operation time	6 days
Daily operation time	10 hours

2.2 PV system

2.2.1 Cernusco sul Naviglio school centre

The PV system consists in 23,5 m² of PV modules.
The PV modules were mounted on the Solarwall solar air collector of one of the gymnasium, according to an integrated PV-Solarwall solution.
The PV modules were mounted on the solarwall collector above the windows strip.
The PV plant provides about 3,08 kW_p in alternate current with secondary voltage from the inverter of 220V.

Solar module SP110 – Siemens	
Electrical parameters	
Module voltage	24 V
Maximun power rating - Pmax	110 W
Rated current - Imp	3,15 A
Rated voltage - Vmp	35,0 V
Short circuit current - Isc	3,45 A
Open circuit voltage - Voc	43,5 V
Size	1316mm * 660mm
N. of modules	27
Total surface	23,45 m²
Inclination	Vertical

The produced elcectricity is discharged in the internal electric grid of the buildings. An inverter changes the direct current produced by PV modules in alternate current.

2.2.2 Pioltello school centre

The PV system, consists in 23,5 m² of PV modules.
The PV modules were installed on the roof of the low building block, where is located the central thermal plant of the school centre, just in front of the south façade of the gymnasiun.
PV modules are 30° slope.
The PV plant provides about 3,08 kW_p in alternate current with secondary voltage from the inverter of 220V.

Solar module SP110 – Siemens	
Electrical parameters	
Module voltage	24 V
Maximun power rating - Pmax	110 W
Rated current - Imp	3,15 A
Rated voltage - Vmp	35,0 V
Short circuit current - Isc	3,45 A
Open circuit voltage - Voc	43,5 V
Size	1316mm * 660mm
N. of modules	27
Total surface	23,45 m²
Inclination	40°

The produced elcectricity is discharged in the internal electric grid of the buildings. An inverter changes the direct current produced by PV modules in alternate current.

2.3 EMS

The realised EMS consisted in peripheral device units connected to a central unit for data collection where the user interface is represented by a Personal Computer.
The EMS was designed for Solarwall system and PV system controlling with the aim to monitor the energy saving results.
Heat contribution from the solar wall is monitored together with the weather conditions (temperature and solar radiation) and electricity production from the two different PV systems is measured. The monitoring is carried out by a data logger system.
Telemonitoring is made by a GSM modem.

3 DESCRIPTION OF THE PERFORMANCE OF THE MONITORING AND MEASURING SYSTEM

The energy management system (EMS) was installed for controlling the innovative technological systems realised in each school centre.
The intention of the contractor was the tele-monitoring and tele-controlling of the regulation and operation of the PV and solar thermal systems.

The management operations are made from the PC and they consist in the following possible actions:

- To control in real time, the system status, the alarms and the commands with reference to all the operating times
- To permit an autonomous management of the energy consumption of the two school sporting centres
- To acquire all data for the continuous monitoring of each plant system (solar plant, PV system).
- To provide expected performance

The EMS measures the performance of the solar wall systems and PV systems during the operation.

Monitoring of the PV system started in April 2002, monitoring of Solarwall system started after 15th october 2001, although the EMS was not yet installed.

3.1 Solarwall system

The objective of the monitoring is to verify the energy saving obtained by using the solar thermal system and to optimise the Solarwall operation on the base of the climatic conditions.
Heat contribution from the solar wall is monitored together with the weather conditions (temperature and solar radiation). The monitoring is carried out by a data logger system.
On the base of the introduced external air, the following data are measured:

- External Temperature
- Temperature of the Solarwall air flow intorduced in the buildings
- Time of Solarwall operation

Temperature sensors have been installed:

- Temperature sensor to measure the external temperature (Te) installed in a sunny place;
- Temperature sensor to measure the temperature of the air introduced by Solarwall in the buildings (Ti), installed on the fan.
- Temperature sensors are thermoresistant type, with measure range -10°C ÷ + 40°C.

Solarwall operation is connected to the opening of the by-pass dumper with thermostastic functions (installed between the fan and the solar collector): the by-pass dumper permits to evaluate the operation time of the Solarwall system.
The signal is aquired by the regulation digital system of the plant.
The aquired data are transmitted to the EMS.
The EMS provides printed data of the measures.

3.2 PV system

The objective of the monitoring is to measure the electricity produced by the solar PV system and to optimise the operation on the base of the climatic conditions.
The real electricity production of the PV modules is compared with the standard electricity production of the modules: this information is provided by the PV modules producer.
The EMS registers the following parameters:

- Daily operation time of the PV system
- Daily electricity production of the PV systems
- Total hours of operation of the PV system from the start of the EMS
- Total electricity production of the PV system from the start of the EMS.

Daily operation time of the system refers to a power production of the modules > 150 W. When the modules produce a power < 150 W, the system is stopped.

4 TIME SCHEDULE

ACTIVITY	TIME
Design – installation – commissioning of the Solarwall facades	August 2000 – December 2000
Waiting for the acceptance of the contractor's withdrawal and the confirmation of the extension of the contract's time by the European Commission	
Design of PV systems and EMS	October 2001
Installation – commissioning of PV systems and EMS	April - May 2002
Start Monitoring	May 2002
End monitoring	July 2003

5 COSTS

Project Phase	Cost submitted	Contract cost
Design	39.349,55	39.958
Construction	182.059,69	145.710
Commissioning	31.450,40	45.927
Monitoring	26.976,64	27.225
Total	279.836,28	258.820

6 PERFORMANCE

6.1 Measurement performances

6.1.1 Cernusco sul Naviglio sporting centre

Solarwall system worked last heating season (2001-2002), but the EMS and the metering system weren't installed.
The metering system is in function from september 2002.
Heating season started on the 15th of October, and Solarwall operation started on that date.
Basing on the data from EMS, it has been noticed that Solarwall system didn't work untill november 2002 and it was probably due to an uncorrected metering system calibration.
The metering system measured 0 kWh.
The metering system has been checked and calibrated and measurements data are reported in the following table.
PV system operation was monitored from May 2002.
The efficiency of the PV system is lower than in Cernusco gymnasium but this is due to the vertical installation of the PV modules. It is expected to have a better efficiency in the winter season.

6.1.2 Pioltello sporting centre

Solarwall system worked last heating season (2001-2002), but the EMS and the metering system weren't installed.
The metering system is in function from september 2002.
Heating season started on the 15th of October, and Solarwall operation started on that date.

Basing on the data from EMS, it has been noticed that Solarwall system worked only 6 times untill now (13/11/02) for a total of 72 hours.
Total energy produced is 1819,99 kWh.
This value appeared quite low and it was probably due to an uncorrected metering system calibration.
As in the Cernusco school centre, the metering system has been checked and calibrated and measurements data are reported in the following table.
PV system operation was monitored from May 2002.
The efficiency of the PV system is higher than in Pioltello gymnasium but this is due to the inclination of the PV modules (40°).

Total energy consumption (kWh/year) (october 2002 – april 2003)

	Thermal energy (kWhth/y)	Electricicty (kWhel/y)
Cernusco sul Naviglio	1.459.751,5	*Not available*
Pioltello	904.800,5	*Not available*

Total energy consumption before the intervention (kWh/year)

	Thermal energy (kWhth/y)	Electricicty (kWhel/y)
Cernusco sul Naviglio	1.936.287,24	477.760 (2001)
Pioltello	1.089.846,63	327.250 (2001)

The above reported energy consumption refer to the whole school centre, both for Cernusco than for Pioltello.
Thermal energy consumption refer to the bills values; they don't take into account the different degree days of the considered years.

Monitored thermal energy saving refers to the following monitoring periods:

Cernusco sul Naviglio: from 14/11/2002 to 07/04/2003
Pioltello: from 14/11/2002 to 04/04/2003

PV system operation was monitored from May 2002 and the total electricity production (may 2002 – april 2003) has been **4338,1 kWhel**.

Cernusco sul Naviglio:
Total electricity production (may-october 2002) = 935,10 kWhel
Total electricity production (nov. 2002 – apr. 2003) = 663,0 kWhel

Pioltello:
Total electricity production (may-october 2002) = 1813,00 kWhel
Total electricity production (nov. 2002 – apr. 2003) = 927,0 kWhel

Total energy saving (kWh/year) (may 2002 – april 2003)

	Thermal energy (kWh_{th}/y)	Electricicty (kWh_{el}/y)
Cernusco sul Naviglio	36.115,0	1.598,1
Pioltello	24.555,0	2.740,0

Thermal energy saving (%): **15%**

Thermal energy saving appears quite little (2,5%) if compared to the total heat consumption of the two school centre, but it's good if referred only to the volume of the gymnasia (15%).

The measuring equipment firstly performed particularly badly and it required a control and set up. Problems interested the Solarwall systems operation.
The monitoring of Solarwall systems was done handly during the first year of operation (2001).

Considering that Solarwall performance hasn't been measured for the whole operation period, it's expected to improve the performance of the system and to obtain a thermal energy saving of 25-30%.

7 OPERATING COSTS

Annual cost for maintenance, repair, control is actually very low. Solarwall systems didn't require maintenance intervention untill now.
There isn't extra operating cost comparing with a traditional air ventilation system, because the solarwall panels don't need any maintenance action when installed (it's an alluminium sheet); PV system generally doesn't require any maintenance action during its lifetime or only at most 1-2% of the installation cost.
The annual maintenance cost has been calculated around 513 EURO/year for the two centres.
The EMS required control and set up.

8 ECONOMIC VIABILITY

Pay-back Time

The "Payback Time" is the indicator for the cost-effectiveness of energy saving projects and it's defined as:

$$P_{proj} = \frac{I_{proj}}{E - M_{proj}} = \text{years}$$

where:
I_{proj}= total (investment) costs of the installation (project), excluding the costs associated with the demonstration, i.e. design, monitoring, and a part of the management and engineering costs.
E = costs of the annual quantity of energy saved or produced,
M_{proj} = difference between the operation costs of the previous/conventional (reference) and of the improved (project) processes.

Thermal energy saving was monitored in the period november 2002 – April 2003.
In the period may 2002 – october 2002 PV system provided a total of 2.748,1 kWhel (426 EURO).
Considering that in summer there is no heat demand by the buildings, we can conclude that the annual energy saving of the project (may 2002 – april 2003) is 60.670 kWhth and 4338,10 kWhel.

This means a total annual economic saving of 5.877,5 EURO.

I_{proj} = 178.300,17 EURO

E = 5.877,50 EURO

M_{proj} = 0,00 EURO (*)

(*) it has been supposed no extra cost comparing with a traditional air ventilation system, because the solarwall panels don't need any maintenance action when installed (it's an alluminium sheet); PV system doesn't require any maintenance action during its lifetime.

The annual cost for maintenance has been calculated for the two sporting centres around 513 EURO/year and it refers to the annual check of the fans and the ventilation system.

$$P_{proj} = \frac{178.300,17}{5.877,50} = 30 \text{ years}$$

The result is better if we consider the financial support of the EU, that is 40% of the eligible cost:

$$P_{proj} = \frac{106.980,10}{5.877,50} = 18 \text{ years}$$

The above reported energy saving refers to the first year of operation, so it is expected to reduce the Pay Back Time of the investment cost improving the systems performance, in the next years of operation.
This will be obtained thanks to the well operation and management of the solar systems and a correct use of the EMS.
The global pay back time appear quite good considering the actual high cost of the PV systems in Italy.

Service Lifetime

The expected service lifetime of the installation is 25 years.

9 ENVIRONMENTAL IMPACT

The main environmental impact of projects consists in the decrease of greenhouse gas emissions, by using solar energy.
Referring to the monitored total energy saving of the project, the avoided CO2 emission is reported in the follow:

Thermal energy saving: 60.670 kWhth/year
Electricity saving: 4.338,1 kWhel/year

Avoided CO_2 emission = **19 ton/year**.

The above reported energy saving refers to the first year of operation, so it is expected to improve the system performance in the next years of operation.
The environmental impact of the project has been evaluated on the base of the following data:

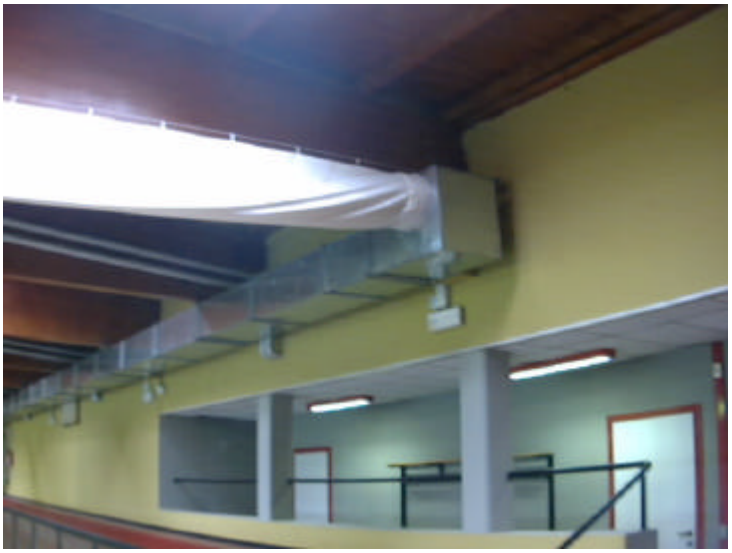
1 MWhth = 0,086 TOE
1 Mwhel = 0,258 TOE

1 TOE of heat by natural gas produces 2,2 ton di CO2
1 TOE of heat by oil produces 3 ton di CO2
1 TOE of electricity produces 3 ton di CO2

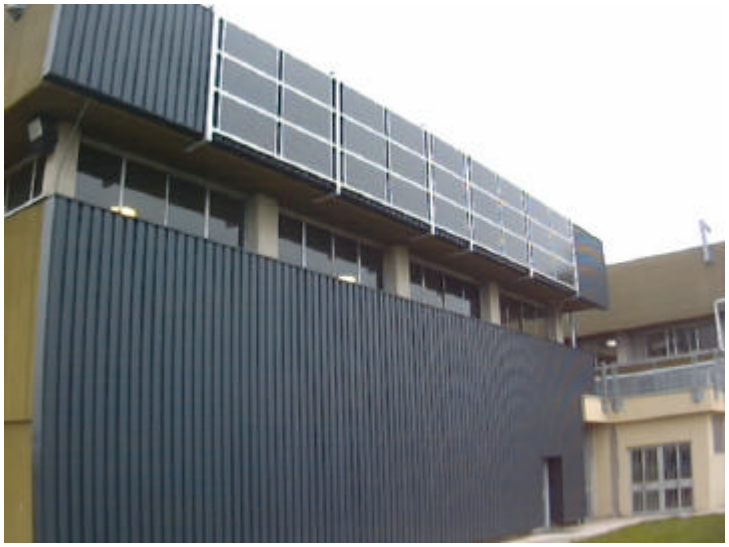
10 PHOTOGRAPHS

Cernusco sul Naviglio: Solarwall air solar collectors on the south facades

Pioltello: Solarwall air solar collectors on the south facades

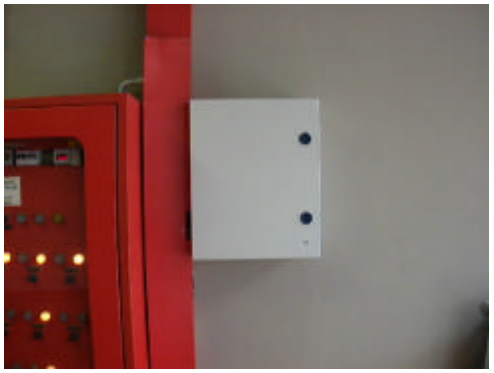


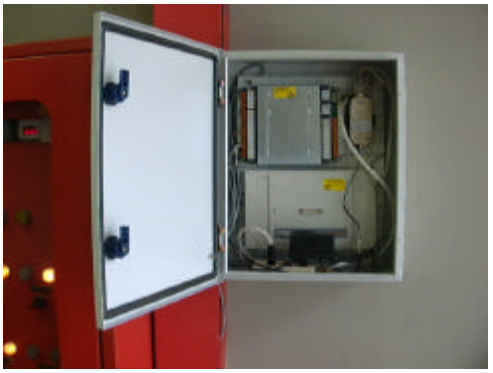
Pioltello: internal air distribution system



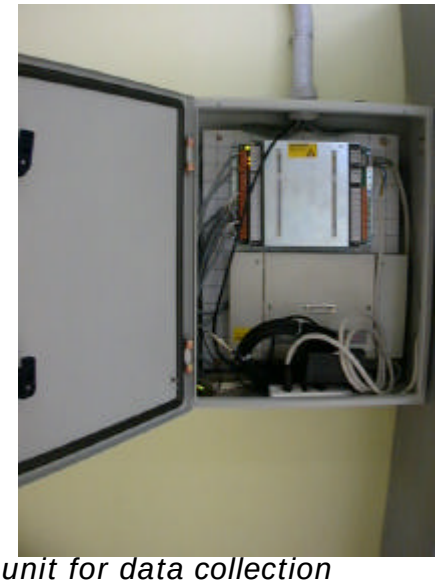
Cernusco sul Naviglio school centre: PV modules mounted on the Solarwall collectors

Pioltello school centre: PV modules on the roof of the thermal central plant.





Pioltello school centre: central unit for data collection



Cernusco school centre: central unit for data collection