Oct 30th, 12:00 AM - 12:00 AM

Energy Efficiency: Case of Study for an Italian Railway Station

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Abstract. The study will analyze the thermal and electrical energy consumption of the largest Italian railway stations, comparing the clustered data from yr. 2014 to yr. 2018, to evaluate the energy consumption trend in TOE, Tonnes of Oil Equivalent.
The aim will be the electrical and thermal consumption reduction, thanks to the use of the photovoltaic technology, integrated with batteries and BACS (building automation and control system).
A specific software (Termolog Design Photovoltaic and Acca Solarius PV) has been used to carry out the results; to identify improvement solutions, an algorithm made it possible to identify the best set point of integration between energy supply and production.

Keywords: Energy Efficiency, CO2 Reduction, Renewable Energy, Photovoltaic System, Eco-Sustainable Development, Green Energy, Circular Economy, Smart Mobility.

1 Introduction

According to the law 115/2008, the Energy Audit (EA), is defined as "a systematic procedure aimed at obtaining adequate knowledge of the energy consumption profile of a building or group of buildings, of an industrial activity, plant, commercial, public or private services, to identify and quantify energy saving opportunities".
More, the Law nb. 102/2014, which transposes in Italy the Directive 2012/27 / EU, indicates the energy audit as one of the fundamental tools to start a sustainable path that can lead to a reduction of energy consumption and emissions. At the same time, it underlines the obligation, for particular subjects, to perform an energy diagnosis periodically (every four years).

In this study the energy consumption of the nb. 14 most important Italian railway stations are reported, indicating that in recent years there has been not a reduction in energy consumption, but an increase. This is due to the growth of the offered services of these large stations and the increasing use of electricity.
The study analyzes a station in particular (the one of Palermo, in Sicily, an Italian Island) and suggests to install a PV system connected to the network and equipped with storage batteries, in order to reduce the energy consumption.

2 Energy consumption of large railway stations

The energy consumption of the main analyzed Italian stations in recent years is shown in Table 1 and Table 2.
The clustered results are carried out from long studies over many years. The reported consumptions are in Tons of Oil Equivalent (TOE). In the case of analysis, the

conversions will be shown in more detail.

Table 1. Energy consumption of the railway station for the year 2014.

#	SITE	Consumption 2014 [TOE]	%
1	Milan CENTRAL	4.626	24,80%
2	Rome TERMINI	3.601	19,30%
3	Turin PORTA NUOVA	2.833	15,20%
4	Naples CENTRAL	2.245	12,00%
5	Rome TIBURTINA	1.441	7,70%
6	Florence SANTA MARIA NOVELLA	1.331	7,10%
7	Verona PORTA NUOVA	685	3,70%
8	Venice SANTA LUCIA	603	3,20%
9	Genoa PIAZZA PRINCIPE	545	2,90%
10	Bologna CENTRALE	356	1,90%
11	Genoa BRIGNOLE	220	1,20%
12	Bari CENTRAL	93	0,50%
13	Venice MESTRE	52	0,30%
14	Palermo CENTRAL	34	0,20%
SUM		**18.655**	

Table 2. Energy consumption of the railway station for the year 2018.

#	SITE	Consumption 2018 (TOE)	%
1	Milan CENTRAL	4.415	20,74%
2	Rome TERMINI	4.271	20,07%
3	Turin PORTA NUOVA	2.905	13,65%
4	Rome TIBURTINA	1.899	8,92%
5	Florence SANTA MARIA NOVELLA	1.709	8,03%
6	Naples CENTRAL	1.654	7,77%
7	Bologna CENTRAL	912	4,28%
8	Genoa PIAZZA PRINCIPE	763	3,58%
9	Verona PORTA NUOVA	731	3,43%
10	Venice SANTA LUCIA	711	3,34%
11	Genoa BRIGNOLE	379	1,78%
12	Venice MESTRE	358	1,68%
13	Palermo CENTRAL	245	1,15%
14	Bari CENTRAL	239	1,12%
SUM		**21.285**	

Figure 1 shows the variations in terms of consumption from 2018 to 2014, considering that most of the stations had an incremental trend in consumption, except for Milan Central and Naples Central.

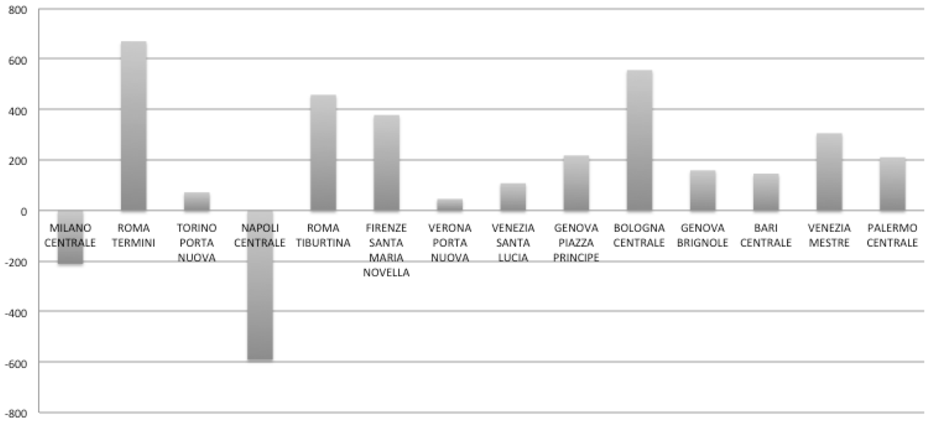

Fig. 1. Change in consumption between 2018 and 2014 in terms of TOE

3 Palermo Central: historical - architectural analysis and energy consumption

3.1 General information about the station

The focus of this work is the Palermo Central Railway Station (Figure 2) , that can benefit from favorable solar conditions and, at the same time, needs to strongly improve the technical conditions.
Built in 1885 and inaugurated on 7 June 1886, it is one of the oldest Italian stations. Its monumental front is testimony to the eclectic architectural style typical of Palermo at the end of the XX century.

Fig.2. Today's photo of Palermo Centrale.

3.2 Energy consumption of the station

The Energetic diagnosis was performed in accordance with Italian Law nb. 102/2014, the further modifications of the Italian Ministry of the Economic Development of May 2015 and the UNI CEI EN 16274 (module 3), based on the documentation provided during the work.
The thermal power plants present in the station are currently not in use. The heating and DHW services in use in 2019 were provided by systems powered by electricity; therefore, the consumption of the railway station was totally electric and no diesel consumption was recorded for 2019.
The distribution of the energy needs was carried out by main activities always linked to the auxiliary systems, but in terms of process services, i.e. those that determine the correct thermo-

hygrometric conditions of the station, auxiliary services and general services.
In this document, all the energy carriers considered are reported following the units of measurement shown in table 4. Each carrier is also correlated with the conversion factor in tonnes of oil equivalent (in accordance with the MISE circular of 18 December 2014).

1. Electricity kWhe → 0,187 x 10-3 TOE;
2. Natural gas Sm^3 → 0.82 x 10-3 TOE

Adjustment factors are variables capable of influencing the energy consumption of a system, such as environmental conditions for buildings and production volumes for industrial sites. Their knowledge is necessary and useful, for example, to translate current consumption data into energy performance and to reliably estimate future ones.
The energy performance indices depend, in fact, on user efficiency as well as on the "surrounding conditions": to consider and analyze only the first aspect, it is important to outsource the latter by normalizing their consumption. The distribution of the energy needs was carried out by main activities always linked to the auxiliary systems, but in terms of process services, i.e. those that determine the correct thermo-hygrometric conditions of the station, auxiliary services and general services. Finally, the synthesis of the electrical and thermal model is reported (see following figures).
Attached to the diagnosis report, the models in detail:

- Average energy consumption of the station for the year 2019 (2018):
  - Electricity Requirement: 253.87 TOE;
  - Thermal Requirement (Diesel): 0.0 TOE.

The almost total consumption, attributable to the Station and is divided between:
- Lighting;
- Electric heating;
- Lifts;
- Air handling unit and refrigeration unit.

Table 3. Subdivision of station consumptions detected by the energy audit.

	kWh	%
Lighting	943.388,82	70,24%
Electric heating	358.809,60	26,72%
Lifts	17.797,40	0,25%
AHU and refrigeration unit	37.449,00	2,79%

4 Energy improvement intervention with a photovoltaic system equipped with storage batteries

The space available for a photovoltaic system (Figure 3) is considerable along the buildings of the station, so it is desired to create a series of dislocated systems, so as to reduce the distance between use and production of electricity.
It was suggested to insert on each building photovoltaic systems from 3 to 8.5 kWp, connected to storage batteries, in order to make these systems autonomous and, theoretically, disconnectable from the grid.
The photovoltaic plants are 15 in total. The total installed power is approximately 118.5 kW (peak).

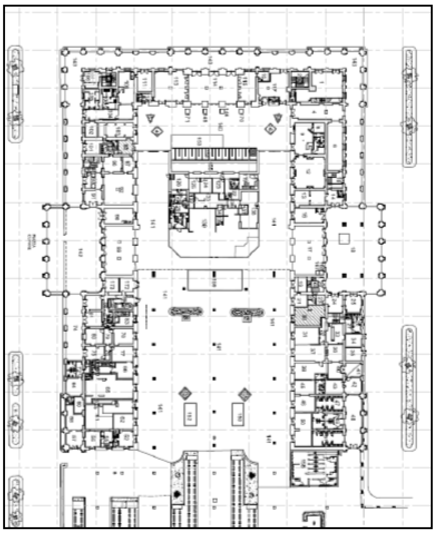

Fig. 3. Available areas for the PV systems.

A software from Acca Solarius PV and SolarGis was used for the simulation and design of the PV system.

Table 3. Productivity of all plants.

Period	Productivity (kWh)
January	7.151,63
February	9.394,94
March	14.581,90
April	18.695,51
May	23.405,34
June	25.077,15
July	25.913,05
August	23.405,34
September	17.616,92
October	12.538,57
November	8.359,05
December	6.408,60
Total Year	**192.548,00**

Evaluating the CO^2 emissions saved by the Italian electricity mix, the saving value is 102.05 tons of carbon dioxide per year.
The annual energy saving of this intervention on the total consumption amounts to 14%, and against an investment of about 212,000 euros (including the batteries and the photovoltaic system); so, the investment presents a short payback period.

Conclusions

In this work has been evaluated the importance of photovoltaic systems, integrated in structures where the electrical demand is in line with the electricity produced by the generation system. The Italian territory is favorable to the electric microgeneration from solar systems thanks to the strong presence of the sun throughout all the territory during the calendar year.

If it is expected to reduce by 15%, the energy consumption of the 14 major stations, thanks to photovoltaic technology, it would have a saving of about 3,000 TOE per year and approximately a reduction of 9,396.00 tons of carbon dioxide per year (data ENEA). It should be remembered that 1 million invested in renewable energy sources, creates 7.5 jobs (data lifegate.it) and the expected value is about 6,300,000.00 €, with over 48 new jobs created for the 14 railroad locations.

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