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# Ethical issues of monitoring sensor networks for energy efficiency in smart buildings: a case study

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**Abstract**

The development of Internet of Things (IoT) based sensors has become crucial for analyzing and optimizing the energy-performance of buildings. However, researchers and professionals should be prepared to deal with the social and thus ethical issues arising from the use of such technologies. Based on a real case-study, we present a detailed analysis of the networks of stakeholders and the consequent ethical issues related to the implementation of energy and IEQ sensors network in an Italian university campus. Alternative scenarios for eliminating or reducing the criticalities related to security and privacy issues are proposed.


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*Keywords:* sensors; Internet of Things, ethics; privacy; security; monitoring; energy; idoor environmental quality; control

## 1. Introduction

Nowadays, sensor-based technologies for the monitoring of energy consumption and Indoor Environmental Quality (IEQ) are becoming a key element for the Heating Ventilation and Air Conditioning (HVAC) systems sector in buildings. Given their necessity to ensure a comfortable environment, sensors are becoming a crucial issue also for energy efficiency [1,2]. In recent years, since the major building technologies (e.g., system efficiencies, envelope insulation, etc…) are reaching their maximum performance physical limit, expectations of further disruptive improvements in the energy performance of buildings are related to sensor-based technologies. On one hand, such

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systems can monitor occupancy and correct bad behaviors. On the other hand, if connected through the Internet to data repositories and weather forecasts, they can improve the system performance by anticipating climate actions with predictive controllers [3] and correct inefficiencies by means of a comparison with good practice benchmarks. Furthermore, present sensor technologies are very cost effective, as the cost reduction of electronic items and the diffusion of wireless networks have dramatically cut down investment and installation costs. This is particularly true in historical buildings, where retrofitting actions are not always possible or economically feasible [4]. Moreover, in existing public buildings, energy savings can be achieved by designing low CapEx ICT-based services to monitor and control environmental conditions, energy loads and systems operation.

A study by Fraunhofer Institute for Building Physics [5] pointed out that an intelligent sensor-based regulation of the heating system can ensure higher energy savings than any other building technology. Furthermore, the study highlighted that 24% of savings are to be ascribed to occupant monitoring and 7% to weather forecast [6], and that high energy savings were achievable by raising awareness about the energy consumption issues in public building occupants. For this reason they designed a monitoring network capable of collecting and communicating coarse energy consumption information in large public buildings. Pesola et al. [7] dealt with remote monitoring of municipality buildings, designing multi-criteria metrics capable of addressing the needs of every stakeholder.

Recently, similar studies were carried out also at Politecnico di Torino. In particular, the projects “Smart Energy Efficient Middleware for Public Spaces” (SEEMPubS) and “WiFi4Energy” dealt with wireless sensor networks for energy management in educational buildings. A tangible result of this project is the setting up of the “Politecnico di Torino Living Lab”, an office that aims at monitoring real time data concerning energy consumption. Politecnico di Torino consumes about 5000 t.o.e of primary energy every year, corresponding to an energy bill of about 4 M€/year. Energy-saving opportunities can thus produce important reductions of operative costs. Nowadays, the sensors network consists in smart meters measuring the power (thermal, electrical, water consumption) absorbed at different levels. Furthermore, in the period 2010-2012, 70 additional IEQ sensors recorded data in different environments (offices, corridors, lecture halls). The purpose was to gain additional knowledge from energy and IEQ monitoring in order to infer some rules driving the energy consumption.

In the “SEEMPubS” project, the idea was to monitor environmental and energy data in real time and to control the operation of lighting and HVAC systems, in order to ensure both energy efficiency and environmental comfort. With regard to lighting, several control logics were adopted according to the use of the rooms, but they were mainly based on occupancy detection coupled with manual control. The lights were programmed to be switched on only in presence of occupants and dimmed to integrate daylighting or to achieve visual comfort. With regard to the heating strategy, a lower set point temperature was maintained during unoccupied hours, and the heating system’s switch off was anticipated when the power from lighting and electrical devices exceeded the heating power’s need [8]. Moreover, in the “WiFi4Energy” project, carbon dioxide sensors were also installed.

The present work focuses on critical ethical aspects related to sensor-based technologies for monitoring the buildings energy consumption and IEQ. The sensors network experiences carried out at Politecnico di Torino were used as case studies to analyze the ethical issues concerning the monitoring of public spaces. The authors of this paper consider it important to specify that they were not directly involved in the above mentioned projects and monitoring experiences (contacts are listed in the acknowledgment of the present paper for interested readers). Firstly, this paper provides a scheme and a framework of stakeholders involved in activities of monitoring public spaces of a university. Secondly, some interviews to the main actors involved in those projects were carried out to identify the main drawbacks and ethical issues that were perceived. Thirdly, the highlighted ethical issues were analyzed in depth and compared with similar case studies from the literature. Eventually, possible alternative scenarios were proposed and their consequences were outlined.

## 2. Description of the stakeholders’ network involved in the monitoring campaign

Figure 1 represents the Politecnico di Torino network of stakeholders involved in the process described in this paper. The key actors are highlighted in the figure with different colors: yellow boxes indicate the policy-makers, blue boxes define the sensors main users, the technology providers are identified with orange boxes and the purple box indicates a possible short circuit in the system (the so called villains represent actors that should not be present, but which still represent an actual threat to the system). Arrows indicate the main direction of communication while