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## Towards an Energy Assessment on an Urban Scale for Retrofitting the Housing Stock in Mediterranean Cities

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### Abstract

According to European Directive 2012/27/EU energy retrofitting of the current housing stock is being promoted. However, few studies have been carried out characterizing housing stock energy performance in order to incorporate energy retrofitting in cities in the southern Mediterranean area. The aim of this paper is to propose an energy assessment methodology on urban scale and to apply it to the southern Spanish province of Cadiz. This is followed by the generation of a predictive model for energy assessment in Mediterranean cities which could be further developed and used in the future to estimate overall energy efficiency on an urban scale.

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### 1. Introduction

During the second half of the 20th century there was a mass expansion of European cities compared to earlier periods, mostly post-war reconstruction. 68% of European housing predates 1980 [1], and most of this housing stock shows clear energy deficiencies which often bring about obsolescence. European Directive 2012/27/EU [2], whose main aim is to establish a common framework of measures for the improvement of energy efficiency within the strategies of Horizon 2020, promotes the adaptation of European regulations and policies, promoting energy retrofitting of current deficient housing stock.

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In this context of change and transformation there is a need to generate new forms of energy assessment, taking into consideration different methods for classification typologies [3] and new approaches on an urban scale. Numerous studies have been carried out focusing mostly on the climate zones of central and northern Europe and providing an energy characterization of residential stock in original condition and following retrofitting [4,5]. However, the unique socio-cultural and climate conditions of the southern areas of the Mediterranean area require a specific approach through research which to date is limited [6]. We highlight the research by Dall'O' [7] which aims to accelerate energy assessment process for urban buildings, calculating consumption values using a comparative statistical methodology which is currently being researched by other authors [8,9]. Although these new methodologies do not provide detailed results for energy efficiency, the information generated can be used by different administrations to plan retrofitting strategies on an urban scale [10,11]. There are several studies employing the same approach by authors from European Union Mediterranean countries such as Greece and Cyprus [12,13].

The main aim of this research is to propose a methodology for the energy assessment of Mediterranean cities on an urban scale and apply it to Cadiz, a province with a Mediterranean climate in the south of Spain. 40% of the current housing stock built in this province predates 1980 [14], when the first Spanish regulations limiting the energy demand of buildings, NBE-CT-79, were implemented [15]. This methodology is proposed as a prior step to the generation of a predictive model for the energy assessment of Mediterranean cities and can be applied in the future to calculate the overall energy efficiency of the entire housing stock of a city.

A typological and constructive classification of the thermal envelope is carried out in order to achieve these goals. During this process it is also necessary to make onsite measurements, to monitor environmental and energy variables, and to simulate previously calibrated energy models. Results will be gathered on a Geographical Information System (GIS) platform. This study will be a useful tool in providing contributions to enhance the knowledge of energy assessment modelling on an urban scale, and to offer support to technicians and managers in charge of sustainable retrofitting plans.

## 2. Methodology

The methodology proposed is organized in four phases:

- Phase I: Identification and analysis of the residential neighbourhoods and association to a GIS.
- Phase II: Energy assessment of residential neighbourhoods and association of the results to a GIS.
- Phase III: Generation of an energy assessment model for Mediterranean cities.
- Phase IV: Application of the energy assessment model to draw up a comprehensive plan for the sustainable retrofitting of residential neighbourhoods, associating the results to a GIS.

This methodology is currently being applied to the case study selected: social housing stock built in the province of Cadiz between 1950 and 1980. This paper reflects its application to an example of a single social housing neighbourhood in the city of Cadiz: the Loreto neighbourhood, built between 1970 and 1975.

### 2.1. Phase I: Identification and analysis of the residential neighbourhoods and association to a GIS.

This phase consists of the following tasks:

Task 1: Case study. A study was carried out in the urban nuclei of the province of Cadiz, analysing multi-family social housing in each of these and defining the corresponding climate zone [16]. This allows us to define the predominant climate area or areas in the province of Cadiz (Fig. 1a), as well as the urban nuclei representative of each of these areas for social multi-family housing, establishing them as case studies for this research.

Task 2: Identification of neighbourhoods and residential neighbourhoods in each of the urban nuclei studied. The aim of this task is to identify the neighbourhoods in each urban nucleus selected as well as the developments from each neighbourhood built in 1950-1980. In order to complete this task the following sub-tasks were carried out in each of the urban nuclei:

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