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Energy performance and thermal comfort of courtyard/atrium dwellings in the Netherlands in the light of climate change

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ABSTRACT

With increased global concerns on climate change, the need for innovative spaces which can provide thermal comfort and energy efficiency is also increasing. This paper analyses the effects of transitional spaces on energy performance and indoor thermal comfort of low-rise dwellings in the Netherlands, at present and projected in 2050. For this analysis the four climate scenarios for 2050 from the Royal Dutch Meteorological Institute (KNMI) were used. Including a courtyard within a Dutch terraced dwelling on the one hand showed an increase in annual heating energy demand but on the other hand a decrease in the number of summer discomfort hours. An atrium integrated into a Dutch terraced dwelling reduced the heating demand but increased the number of discomfort hours in summer. Analysing the monthly energy performance, comfort hours and the climate scenarios indicated that using an open courtyard May through October and an atrium, i.e. a covered courtyard, in the rest of the year establishes an optimum balance between energy use and summer comfort for the severest climate scenario.

1. Introduction

1.1. Background

In the light of energy reduction, transitional spaces have been recognised as a way to receive natural light and air [1–9]. These spaces have been used for 5000 years [10,11], and have emerged in different types for varied purposes. These spaces cover a wide range of spaces from a balcony and a corridor to a courtyard or an atrium. Transition zones are the in-between architectural spaces where the indoor and outdoor climate is moderated without mechanical control systems. In these spaces the occupant may to a certain extent experience the dynamic effects of changes in the outdoor climate. Typically transitional spaces have different interactions with the outdoor environment depending on the climate. In hot climates, they are open to the sky to ease night radiation flux [6,12–14]. Steemer et al. [15] proposed six archetypal generic urban forms for London (51°N) and compared incident solar radiation, built potential and day-lighting criteria. They concluded that the courtyard performs best among these six archetypes. In humid regions, they are used to ventilate buildings and reduce humidity [16–19]. Okeil [20] generated a built form named the Residential Solar Block (RSB), which later was compared with a slab and a pavilion court [21]. The RSB was found to lead to an energy-efficient layout for a hot and humid climate of UAE at a latitude of 25°N. Regarding the importance of ventilation in hot arid and humid climates, Al-Hemiddi and Megren Al-Saud [22] demonstrated that the cross ventilation in a courtyard results in significant enhancement of cooling the interiors and providing thermal comfort. Regarding the orientation [23], in a hot arid environment with measurements showed that in two identically shaped and similarly treated courtyards, but differently oriented, East-West direction provides much more thermal discomfort than North-South. In colder environments, courtyards are covered and glazed to capture solar energy and reduce heat loss [24–27]. Aldawoud and Clark [5] in a comparison between courtyard and atrium in four different cities in the US showed that the open courtyard building exhibits a better energy performance for the shorter buildings, while at some point the enclosed atrium exhibits a better energy performance for tall buildings. They also discussed that different factors like glazing and climate parameters play important role in the efficiency of an atrium. Last but not least, in snow climates, a group of buildings forming an urban courtyard protects itself against cold winds [8,28].

This paper investigates courtyards, common in hot climates, as a possible passive strategy for buildings in temperate climates. More precisely, the courtyard and the atrium (covered courtyard) as transitional spaces will be analysed in this paper to see if they could be applicable and effective for dwellings in the Netherlands by 2050. Finally, the paper will conclude whether courtyards or atria,

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or a combination of both, can provide a more energy-efficient and comfortable indoor environment for the temperate climate of the Netherlands. In other words, the main question for the study presented is whether the use of transitional spaces can be a solution for temperate climates if these become subject to climate change.

1.2. Climate change in the Netherlands

There is a growing concern about the use of fossil energy and its implications for the environment. After decades of debate, the human influence on the climate seems near to certain, supported by a vast majority of climate scientists gathered under the International Panel on Climate Change [29]. NASA has identified eight effects of rapid climate change. These are: global temperature rise, warming oceans, shrinking ice sheets, declining arctic sea ice, glacial retreat, sea level rise, extreme weather events and ocean acidification. The exact extent to which these effects of climate change will occur, and in which timeframe, is subject to uncertainty. Therefore the IPCC works with different variants, sets of probabilities, each leading to different outcomes for the temperature increase and sea level rise. The Royal Dutch Meteorological Institute (KNMI) has translated the IPCC variants to four main scenarios in the near future in 2050, divided as in a matrix of two times two: a moderate and warm scenario (+1 °C, +2 °C temperature increase respectively) versus unchanged or changed air circulation patterns. Fig. 1 presents these four scenarios.

Based on these scenarios, Fig. 2 presents the expected number of summer days with temperatures exceeding 25 °C (the mean temperature in the Netherlands is around 10 °C).

Table 1 presents an overview of climate characteristics for each of the four climate scenarios.

Recent insights indicate a greater probability towards W (Warm) and W+ (Warm+) rather than G (Moderate) and G+ (Moderate +), implying higher temperatures throughout the year as well as dryer summers and wetter winters. For residential buildings, this is important, since these for indoor comfort need to be adjusted to higher outdoor temperatures. Preferably this needs to be done without mechanical interventions, because correction by means of air-conditioning units would increase the consumption of fossil fuels, thereby further aggravating climate change and heating up urban areas locally due to waste heat from the cooling device.

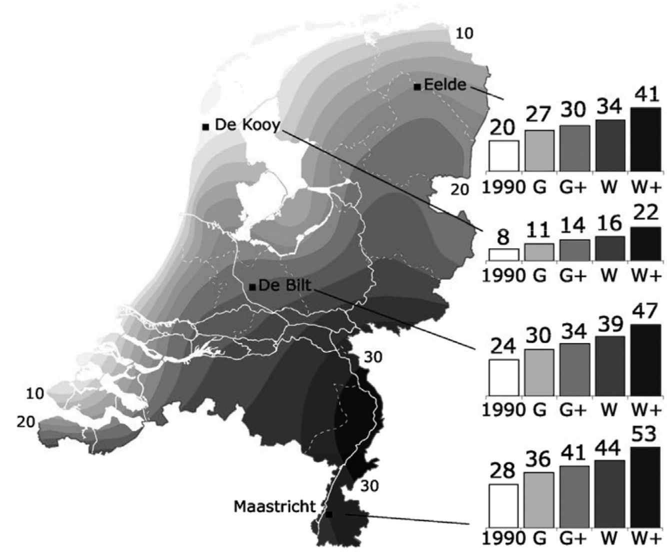
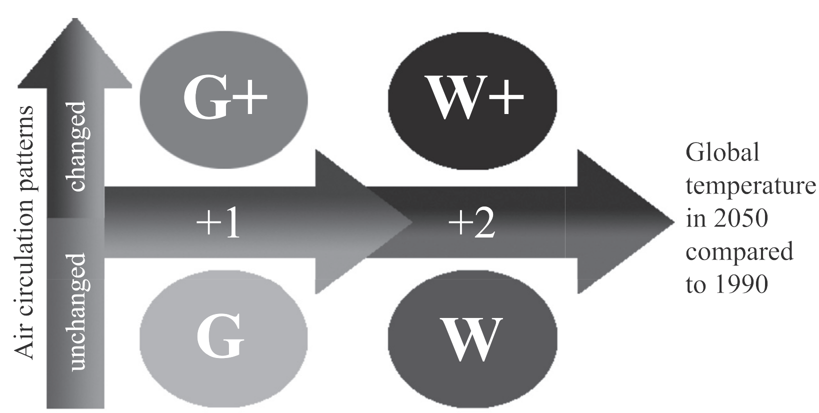


Fig. 2. Calculated effects on the number of summer days in case of the four climate scenarios for the Netherlands in 2050 [30].



G	Moderate	1 C temperatrue rise on earth in 2050 compared to 1990 no change in air circulation patterns in Western Europ
G+	Moderate	1 C temperatrue rise on earth in 2050 compared to 1990 + milder and wetter winters due to more westerly winds + warmer and drier summers due to more easterly winds
W	Warm	2 C temperatrue rise on earth in 2050 compared to 1990 no change in air circulation patterns in Western Europe
W+	Warm	2 C temperatrue rise on earth in 2050 compared to 1990 + milder and wetter winters due to more westerly winds + warmer and drier summers due to more easterly winds

Fig. 1. Four climate scenarios for the Netherlands in 2050 [30].