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Assessing the feasibility of using the heat demand-outdoor temperature function for a long-term district heat demand forecast

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Abstract

District heating networks are commonly addressed in the literature as one of the most effective solutions for decreasing the greenhouse gas emissions from the building sector. These systems require high investments which are returned through the heat sales. Due to the changed climate conditions and building renovation policies, heat demand in the future could decrease, prolonging the investment return period.

The main scope of this paper is to assess the feasibility of using the heat demand – outdoor temperature function for heat demand forecast. The district of Alvalade, located in Lisbon (Portugal), was used as a case study. The district is consisted of 665 buildings that vary in both construction period and typology. Three weather scenarios (low, medium, high) and three district renovation scenarios were developed (shallow, intermediate, deep). To estimate the error, obtained heat demand values were compared with results from a dynamic heat demand model, previously developed and validated by the authors.

The results showed that when only weather change is considered, the margin of error could be acceptable for some applications (the error in annual demand was lower than 20% for all weather scenarios considered). However, after introducing renovation scenarios, the error value increased up to 59.5% (depending on the weather and renovation scenarios combination considered). The value of slope coefficient increased on average within the range of 3.8% up to 8% per decade, that corresponds to the decrease in the number of heating hours of 22-139h during the heating season (depending on the combination of weather and renovation scenarios considered). On the other hand, function intercept increased for 7.8-12.7% per decade (depending on the coupled scenarios). The values suggested could be used to modify the function parameters for the scenarios considered, and improve the accuracy of heat demand estimations.

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Keywords: Heat demand; Forecast; Climate change

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1. Introduction

District heating networks are commonly proposed in the literature as an environmentally friendly solution for providing heating services for urban environment. Centralized heat production located outside municipalities, utilization of renewable heat sources (biomass, solar, geothermal etc.) and comfort for the consumers are usually stated as the main benefits of such systems. The subject has been widely researched in several scientific reports [1-4]. The conclusions were that the district heating should be considered as an essential cost effective technology for the EU energy system decarbonization. The construction of such infrastructure requires significant investments costs, which are returned through the heat sales. However, due to the changed weather variables caused by the climate change, the amount of heat required to maintain comfort indoor conditions could decrease in the future. Additionally, new governmental policies that tackle the refurbishment of the existing building stock (such as EPBD - Energy Performance of Buildings Directive, or the Directive 2010/31/EU), along with the implementation of advanced construction and insulation for new buildings, could decrease the heat loss through the building envelope. Consequently, heat demand could decrease even further. Thus, modelling the future heat demand evolution in the decades to come could be the crucial aspect for assessing the district heating networks construction/expansion project feasibility.

Nomenclature

T_{ht}	heating threshold temperature [°C]
T_{ct}	cooling threshold temperature [°C]
$Q_{h,i,j}$	hourly heat demand of the *i*-th building for the regarded *j*-th hour [W]
α_i	heat demand – outdoor temperature function slope for the corresponding *i*-th building [W/°C]
θ_i	heat demand – outdoor temperature function intercept for the corresponding *i*-th building [W]
$t_{o,j}$	outdoor air temperature for the regarded *j*-th hour [°C]
θ	heat demand – outdoor temperature function intercept for the corresponding building [W]
Δ	annual heat demand percentage error [%]
σ	standard deviation between the hourly demand values [-]
$Q_{hdf,j}$	hourly district heat demand estimated by the heat demand-outdoor temperature function [W]
$Q_{hdRC,j}$	hourly district heat demand estimated by the RC model [W]

The impact of climate change on building heat demand was already addressed within the existing bibliography. Based on the study scale and weather scenarios considered, these studies can commonly be categorised into three major groups:

- **Building scale, one location** – one representative building was selected for the location studied, with weather scenarios developed based on the local climate [5-6];
- **Building scale, multiple locations** - one representative building from the national building stock was selected, with weather scenarios developed for all major climate types found within that particular country [7-10];
- **Large scale (district/city/country level)** – methodologies developed were applied on a large building sample (that vary in both type and construction period), with single or multiple weather scenarios considered [11,12];

Within these studies, to calculate the heat demand, the authors either used detailed simulation software such as Energy Plus and TRNSYS (for the case studies on a building scale), or estimations based on the statistical data (for large-scale case studies). However, urban environment is usually consisted of various building types originating from different construction periods that can differ significantly in both size and geometry. Thus, up-scaling the heat demand calculated for a representative building or downscaling the demand calculated on a statistical basis could

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