Energy Aware Interactive Design: experimenting with city morphology

Azarakhsh Rafiee, Eduardo Dias, Michael Batty and Henk Scholten

1. Introduction

The urban population is growing rapidly and so does its energy demand. An influential share of energy usage in cities is ascribed to residential/office buildings. Therefore, understanding the factors which influence energy consumption in buildings can help us create solutions to reduce energy demand. The relationship between energy consumption profiles and urban morphology (including a.o. tree volumes and building configuration) have been estimated. we then propose an indicator that encapsulates the impacts of these urban settings on energy consumption. This indicator can be used by spatial designers and planners to get direct feedback of the impacts of their designs and interventions on energy consumption. Cost indicators and restricting regulations have also been integrated in the design tool to steer the process for an optimal design.

2. Goal and objectives

We intend to estimate the impacts of the building volume, tree volume and building material on energy consumption in winter and summer separately. Furthermore, we want to estimate these parameters for London and Amsterdam to compare the results. We have used summertime and wintertime energy profiles of the study area. High detailed and accurate 3D tree models, 3D building models and buildings surface albedos are used so that their impact on energy consumption of different regions be estimated. Estimating these parameters we have developed indicators which present energy consumption probabilities for different regions of London and Amsterdam. We have used City Engine to implement our developed indicator. Each time a user designs new neighbourhoods, including buildings and trees, the indicator value will be updated. This way, the user can visualize the consequences of his design on energy consumption.

3. Methodology

3D building models

Using 2D building footprints and LIDAR height data, we have created 3D building models of the study area. For each 3D building model we have calculated its surface to volume ratio.

3D tree models

3D tree models are created from LIDAR data using Silvistar model. For each 3D tree model, its volume has been calculated. Figure 1 presents the 3D tree and building models of a neighbourhood.

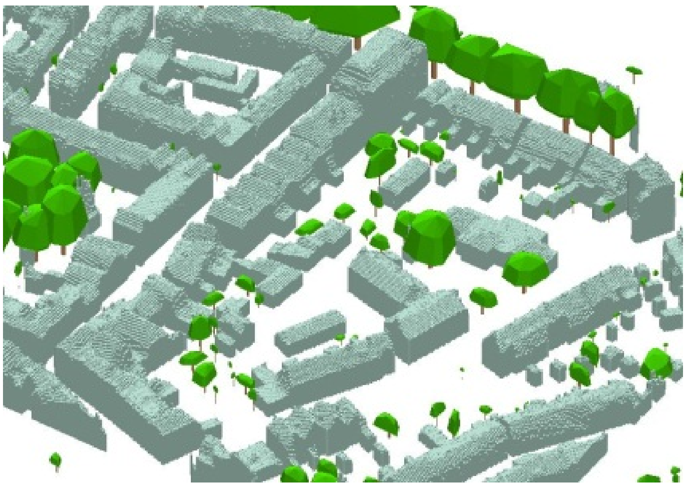

***Figure 1**. 3D tree and building models*

Rooftop surface albedo
Albedo maps of all the rooftops of the region have been generated through the satellite images.

Relationships between neighbourhood characteristics
We have divided the study area into different neighbourhoods (depends on the energy consumption profile scale). For each neighbourhood we have calculated the average building density, total tree volumes and the average buildings' surface to volume, the average rooftop albedos. Extracting the consumed energy from the profile we calculate the share of each above mentioned parameter. We have done that for summertime and wintertime separately to see the share of the parameters on cooling and heating energy consumption.

Energy consumption probability indicator
Estimating the share of each parameter in energy consumption of neighbourhoods, we have formed an indicator which encapsulates the impacts of these urban settings on energy consumption. We have created two separate indicator, one for summer and the other for winter. That is because the above mentioned parameters can have conflicting roles in summer and winter energy use.

Cost Indicator
We have developed cost indicators for trees and building materials.

Restricting regulations
We have simulated some restricting regulations for building densities, heights and building materials.

Implementing the developed indicators in a design environment
We have implemented the developed indicator in a design environment. Our indicator is dependent on building density, surface to volume ratio, rooftop albedo and tree volumes. If the user change one or more of these parameters the indicator value will be updated immediately. Cost indicators have been implemented into the design environment in a similar way and their values will be updated each time a parameter changes. Restricting regulations are also in the design environment to control the design for free spaces, buildings heights, etc. Figure 2 presents an example of such a design environment in CityEngine.

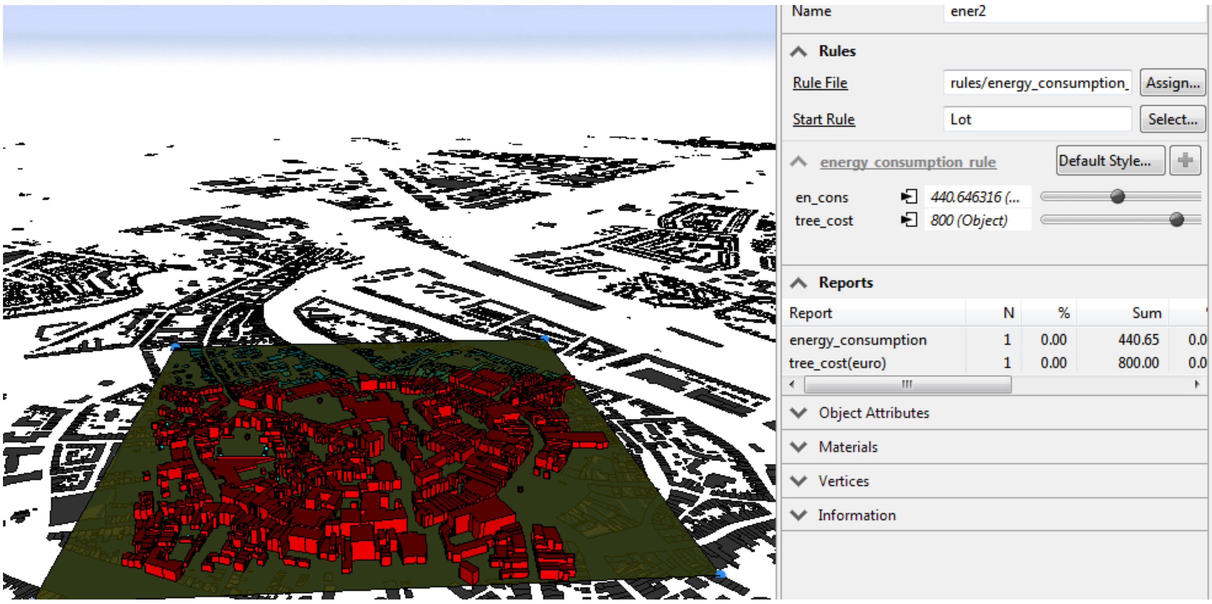

Figure 2. *Energy consumption indicator in a design environment (CityEngine)*