Dynamic Energy Mapping Project Outline

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Contents

Abstract

This document provides an approach of adding the "time" dimension to an Energy Map. The approach is demonstrated with a model of a conceptual urban setting created in CityEngine based on the extracted topological and density pattern from an existing urban design project. The buildings in the conceptual model is then assigned an energy profile of certain DOE Commercial Benchmark Building Reference model based on its building type. Hourly energy demand profile of heating and cooling end use is then obtained from the EnergyPlus Reference models. The energy consumption data is classified into groups with consideration of building energy design context and the data distribution properties. A corresponding color coded energy profile is then generated and imported to CityEngine. 8760 color coded 3D map images was then extracted from CityEngine with Python script. A data reading, ploting, color-coding calculation and a user interface for visualizing the images and dynamic data plot with sliders is implemented using Python and related packages. The tool is anticipated to provide decision support for community energy management and planning, demand-side strategy design and district system sizing.

The document will also briefly discuss one of the testbed for data classification and visualization.

1 General Introduction

1.1 Definition of Energy Map: Urban Energy Geo-database

In a restricted sense, Energy Map is an instance of a thematic map that depicts energy information. More generally, an energy map is an abstract representation of some energy feature in an urban environment. It is useful in providing qualitative or quantitative insight of the energy feature it represents. The energy related features depicted in an energy map can be classified into two major categories: the supply side and the demand side. The following discussions will be based on the two main categories.

Energy map is a hibernation of two types of databases: building energy database, a subset of the BIM (Building Information Model) system and GIS (Geographical Information System). The basic functions of an energy map includes 1) storing energy data in an organized fashion, that facilitate easy analysis and query of energy data and 2) provide reports in the form of graphs, tables, animations etc that conveys numerical information in a way that best support pattern recognition and decision support.

1.2 Why "time" dimension is important for an Energy Map

1. Demand Side is strongly time dependent

   The demand of energy is strongly dependent on weather condition and building types, operation schedules. Weather conditions have strongly seasonal pattern and periodical daily pattern. This type of variation takes the form of a global influence on heating or cooling load. The building operation schedule of different building types vary greatly which indicate a non-coherent arrival of peak demand. In order to match the supply side to the demand side, understanding the strongly the spatial-temporal pattern of the energy demand is crutial.

2. Supply Side should better match the demand side in energy supply timing and intensity for reducing total consumption

   The major energy source used in the building sector are electricity and natural gas: according to CBECE 2003, 3559 tBtu electricity and 2100 tBtu natural gas were consumed for the commertial building sector, making up 55% and 32% of total energy consumption of commertial buildings [1]. In RECS 2009, the space heating (42%) and lighting and appliances (30%) accounted for over 70% of residential energy consumption [3].

   As the result of the finiteness of fossil fuels, the using of renewable energy begins to come into play. In 2013, renewable energy account for 9% of the residential and commercial primary energy source [2].

3. Community Energy Planning and District system design requires a more detailed picture of the energy temporal behavior on community level

1.3 General Description of Dynamic Energy Map

1. Dynamic Map holds 8760-hour meta data of energy demand and supply

2. Dynamic Map has multi-dimensional graphical display of the meta data in conveying spatial-temporal pattern

    2.1. 1D: data plot for providing quantitative information

    2.2. 2D/3D: graphical display of spatial relationship of energy data

    2.3. 1D + 2D/3D: interactive graphical display of spatial-temporal pattern of energy data

2 Related Works

2.1 Energy Map (without temporal dimension) (grouped with field of application)

1. Supply side: Assessing renewable energy potential

   1.1. "Evaluation of Renewable Energy potential using a GIS decision support system", Voivontas et al., 1998

   1.2. "Spatial mapping of renewable energy potential", Ramachandra and Shruthi, 2007

   1.3. "Energy Potential Mapping: Visualizing Energy Characteristics", Dobbelsteen et al. , 2013

   1.4. "NYC City Solar Map": present solar energy potential for buildings across the city. Information presented include: solar energy generation curve, estimated solar system installation area, finantial incentive and payback etc`http://www.nycsolarmap.com/`.

2. Supply and Demand Side: Analysis or design support of existing energy infrastructures

   2.1. "Developments to an existing city-wide district energy network Part I: Identification of potential expansions using heat mapping", Finney et al. , 2012

   2.2. National Heat Map, `http://tools.decc.gov.uk/nationalheatmap/`

3. Demand Side: Energy consumption prediction model

   3.1. "A large-scale study on predicting and contextualizing building energy usage", Kolter, J. Zico; Ferreira Jr, Joseph.

4. Smart Management of Urban Energy System

   4.1. "Smart Urban Services for Higher Energy Efficiency"(SUNSHINE) project (2013): energy consumption map, automatic alerts, remote control of public building lighting system.

References

[1] EIA. Table c1a. total energy consumption by major fuel for all buildings, 2003. web, December 2003. http://www.eia.gov/consumption/commercial/data/archive/cbecs/cbecs2003/detailed_tables_2003/2003set14/2003html/c1a.html.

[2] EIA. Monthly energy review. web, May 2014. http://www.eia.gov/energyexplained/index.cfm?page=us_energy_homes.

[3] EIA. Use of energy in the united states explained energy use in home. web, July 2015. http://www.eia.gov/energyexplained/index.cfm?page=us_energy_homes.