Topic D1: Smart and mobile technologies

ONLINE MAP OF BUILDINGS USING RADIANT TECHNOLOGIES

Caroline KARMANN[1,*], Stefano SCHIAVON[1] and Fred BAUMAN[1]

[1]Center for the Built Environment, University of California Berkeley, CA, US

[*]Corresponding email: ckarmann@berkeley.edu

Keywords: Map, Radiant systems, Building database, Case-Studies, Online resource

SUMMARY

Radiant cooling and heating systems have the potential for energy savings in buildings. Yet, depending on the world region, type of system, and conditioning mode, they have not been uniformly adopted. To address this disparity, we collected data on notable buildings using radiant systems with a focus on North America, type of system, conditioning mode and architectural value. We then integrated these examples into a publicly available online map. The goal of this project is to provide resources to building stakeholders, to connect them and to contribute to on-going research and design on radiant systems. To collect the data, we used peer-reviewed publications on case-studies, articles from architectural magazines and we contacted buildings professionals. The map currently shows 90 buildings. Information for each building is classified into 12 categories. Buildings can be displayed by radiant system type (embedded surface systems; thermally active building systems; radiant panels) or by building type.

INTRODUCTION

Radiant cooling and heating systems are able to maintain high comfort while using a fluid at a moderate temperature (Babiak et al., 2009). This makes them interesting to consider in combination with primary energy conservation systems and sources (e.g., heat pumps, geothermal exchange, solar systems) for energy efficient buildings.

While radiant systems are more quite commonly adopted in Europe, their design and application are still considered in development in the United States (Thornton et al., 2009). Beside this geographical disparity, there are variations in terms of type used and conditioning mode: Olesen (2012) observed that thermally active building systems (TABS) are not yet widely distributed in the United States and Asia, and according to Tian and Love (2009), radiant cooling applications are still rare in North America. The lack of familiarity (Tian and Love, 2009), the risk of condensation in cooling (Mumma and Jeong, 2005) and the complexity on sizing radiant systems (Bauman et al., 2013, Feng et al., 2013) are among the main limiting factors.

Based on the need for improved energy efficiency in the building sector (goal of Net Zero-Energy Buildings for all new commercial buildings in the United States by 2030 (Congress US, 2007)), as well as the lack of widely available information on completed radiant projects, our motivation is to help spread knowledge on these systems, leading to growth in the technology and wider implementation of successful projects.

Geographical information system (GIS) is a computer system that gathers, stores, and analyses geographical information, and displays it on demand. With the development of the World Wide Web (Web), GIS saw an explosion: applications such as Google Maps suddenly allowed the public to share a huge amount of data (Miller, 2006). Web-GIS can function as an interface to geographic and non-geographic information and can be part of a search engine (Kraak, 2004). Web-GIS has provided powerful tools in various academic, civic, and political disciplines (Miller, 2006) and has led to numerous applications, including climate change, health, and natural disasters (Chen et al., 2009). With the increasing availability of geospatial databases in science, technology and innovation, there is a growing interest for GIS technologies and visualization alternatives in these fields (Kwakkel et al., 2014).

The aims of this research are to collect data about radiantly conditioned buildings and develop a publicly available online map. By mapping representative buildings using radiant systems, our goals are the following: a) provide resources to building stakeholders, especially in world regions where these technology are less popular; b) connect designers at a local and global scale; c) contribute to on-going research by connecting researchers with a large set of implemented cases in order to facilitate further studies (field measurements post-occupancy study).

METHODOLOGY

This section describes the data we looked for, what criteria was used for selection, how it was collected and organized, and the mapping software that was used.

Data collection and sorting

Two levels of detail were used to collect data: general information about the building and specific information about the radiant system. The map should provide enough information to be a relevant source for building stakeholders, but at the same time, it should have a reasonable amount of information to display. The data sought for each case is summarized in Table 1. The following four main sources were used to collect data: 1) peer-reviewed publications on case-studies (e.g., Kalz (2009), GeoTABS (2011)); 2) online form for practitioners based on the categories shown in Table 1 and accessible under the CBE Website (http://bit.ly/RadiantFormCBE); 3) available web-articles and case-studies (e.g., EnOB (2014), AIA (2014), GreenSource (2014)); and 4) books on radiant systems (e.g., Moe (2010)).

Building type and radiant system type were the major categories used for classification. The types of radiant systems followed the international standard ISO 11855 (ISO, 2012), the European standard EN 15377 (CEN, 2008), the ASHRAE Handbook on HVAC Systems and Equipment (chapter 6) (ASHRAE, 2012) and the REHVA guidebook (Babiak et al., 2009). The following three main types of radiant systems have been identified:

- Embedded surface systems (ESS): the pipes are embedded in the surface of the slab/wall but are insulated from the structure (EN 15377 / ISO 11855, type A, B, C, D, G);
- Thermally active building systems (TABS): the pipes are embedded in a massive concrete slab/mass (within the structure) (EN 15377 / ISO 11855, type E)
- Radiant panels: the pipes are attached to panels which are fixed to the construction by means of hangers (ASHRAE, 2012, Babiak et al., 2009).

Table 1: Information about the building and the radiant system

Information	Category	Comment
on the building	Building name	
	Building location	*Address or if known geographical coordinates (latitude, longitude)*
	Year Built/Retrofitted	*Both reported in the case of a retrofit*
	Building type	*By category:* Office; School (K-12); University; Laboratory; Retail; Museum/Exhibition; Multi-purpose; Hotel/Dormitory/Residential; Theater/Assembly; Transportation; Other
	Building area	*ft^2 or m^2*
	Climatic zone	*Based on ASHRAE 90.1-2010 or other*
	Owner and design team	Owner; General contractor; Architect; Radiant system designer
	Certification / Award	
	Web links	
on the radiant system	Type of radiant system	*By category -multiple answers possible* - Embedded Surface System (EN15377, type A, B, C, D or G) - Thermally Active Building Systems (EN 15377, type E) - Radiant panels (ASHRAE, 2012) - Other
	Conditioning mode	Heating and/or cooling
	Radiant system description	*Surface that includes the radiant system (floor, ceiling, walls) and how it is it built (layers/material involved)*
	Radiant zone description	*Type of spaces in which the radiant system is implemented, size, orientation, envelope construction, solar control*
	Energy source	*Energy source linked to the radiant system*
	Air system	*Ventilation system used in combination with the radiant system*
	Product information	*Manufacturer and product name*

Selection and distribution of projects

The implementation of water-based radiant systems is geographically heterogeneous. In some regions, the number of cases is high. In these locations, the technology is usually well represented in publications and is well-known by the designers. The goal of the map is not a complete census of all constructed radiant system projects, but to offer a useful resource for building stakeholders. We decided to prioritize our selection of buildings to regions showing a high potential for these systems but with limited applications. For example, in comparison to Europe, North America has far fewer examples of radiant installations so we have focused our attention primarily to this region. For regions with a high density of radiant systems, we decided to prioritise best practices and significant projects: the building is a ground-breaking radiant system, or it has been analysed with a post-occupancy evaluation, or it architectural awards. We had a similar approach regarding the different types of water-based radiant systems: our focus was on EES and TABS which are less spread than radiant panels. Finally, the same argument is valid regarding the different conditioning mode: radiant cooling is less spread than radiant heating because it is offers more challenges from the technical standpoint (condensation issues, solar loads, cooling load calculations) and therefore we were particularly interested in cooling applications.

Types of maps, online mapping application and database management

We conducted a review of available maps with a focus on building design information. As the data we collected do not include virtual models, we limited our search to two dimensional maps. We could find three families of maps: maps based on points (geographical markers), maps based on lines, and maps based on surfaces. Maps based on geographical markers presented the closest examples of what we had in mind (e.g., Net Zero Energy Building map, Bergische Universität Wuppertal (2013)). We decided to use for this type of map, with buildings represented by markers. Various online mapping applications were considered. We wanted an application which would be free, easy to implement (create/update the map), and whose outcome (online map) would be familiar to most viewers. The application should also allow possible export/import with XML and KML formats in order to let map users download the data and import it into further geographical applications. The summary of online free mapping applications tested is shown in Table 2. We decided to use Google Mapsengine Lite. As both existing and new buildings are expected to supplement the current map, data needs to be permanently updated. The information sent via the online form from practitioners is gathered by CBE who is in charge of reviewing and organizing the data and publishing the map.

Table 2: Online free mapping applications considered

Mapping tool	Pros	Cons
Google Mapsengine Lite	- easy to create the map - map interface familiar by most web users (Google map) - XML / KML compatible	- medium flexibility on how to display results (custom functions available)
Google Fusion table	- easy to create the map - map interface familiar by most web users (Google map) - XML / KML compatible	- low flexibility on how to display results
Batchgeo	- easy to create the map - map interface familiar by most web users (Batchgeo uses Google map) - XML / KML compatible	- free version has low flexibility on how to display
Google Maps JavaScript API v3	- high flexibility on how to display results - map interface familiar by most web users (Google map) - XML / KML compatible	- requires programming skills to create/update the map

RESULTS AND DISCUSSION

The result of our study is a two dimensional Google map publicly accessible from any Web browser (http://bit.ly/RadiantBuildingsCBE) (see Figure 1). Links to the map are included within the CBE website and within the Wikipedia page on radiant systems. In total, data from 90 buildings using radiant systems currently appear on the map. Table 3 breaks down these cases by category.

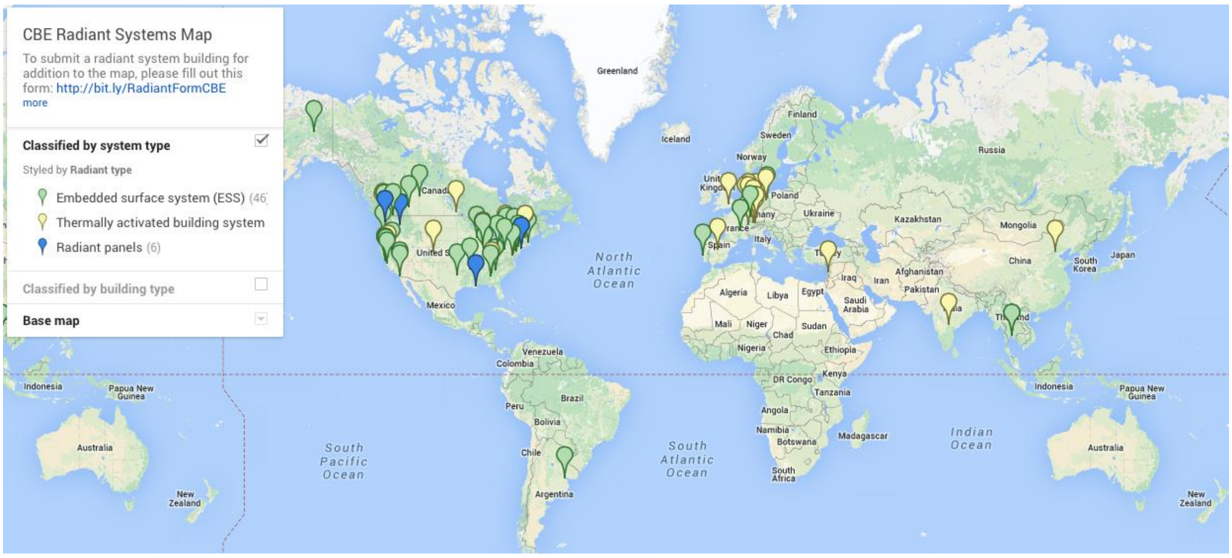

Figure 1: Screenshot of the map with buildings classified by radiant system type

Table 3: Building database

Categories	Sub-category	Number of buildings
Radiant systems type	Embedded Surface System	46
	Thermally Active Building Systems	38
	Radiant panels	6
Building type	Office	29
	School (K-12)	6
	University	13
	Laboratory	9
	Museum/Exhibition	9
	Retail	4
	Theater/Assembly	1
	Hotel/Dormitory/Residential	4
	Transportation	3
	Multi-purpose	10
	Other	2

The map is filled with colored markers representing buildings using radiant systems. The map allows users to display their results by type of radiant system or by building typology. This function is available on the map using layers shown in the legend box on the top left. Markers will be coloured based on these categories. By clicking on a marker, a dialog box opens and displays the information related to that building. We wanted to have a systematic format which would help map viewers to easily find the information. In order to allow maximum readability, we wanted to limit the size of the dialog box, i.e., the quantity of information shown. Based on the data collected (see Table 1), 12 categories are used to describe each building on the map (see Figure 2).

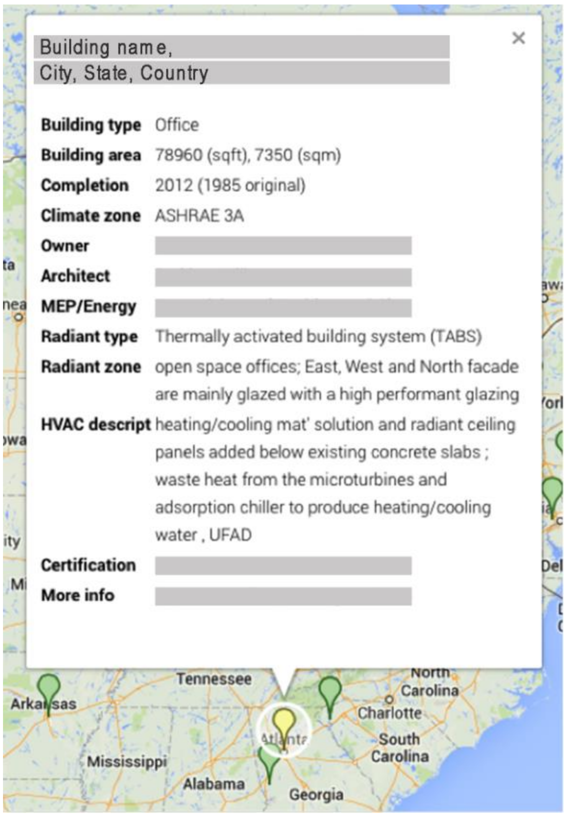

Figure 2: The dialog box, which displays building information on each building

The map was first focused on ESS and TABS and on North American examples. As we enlarged our scope to all types of systems and worldwide cases, we wanted to keep the focus on regions with a high potential for these systems but few applications. This decision is related to our first goal of providing a resource to building professionals in regions where these technologies are less known.

CONCLUSIONS

A publicly available online map (http://bit.ly/RadiantBuildingsCBE) on radiant system projects has been created. This map is linked to a database of buildings using these systems. Ninety buildings are in the database, of those 29 are offices, 13 are universities, 10 are multi-purpose buildings, 9 are laboratories, 9 are museum/exhibitions spaces, and 6 are schools. The database includes 46 ESS, 38 TABS and 6 radiant panel systems. Information is classified into 12 categories available for each building.

ACKNOWLEDGMENT

This work was supported by the California Energy Commission (CEC) Public Interest Energy Research (PIER) Buildings Program. Partial funding was also provided by the Center for the Built Environment, University of California, Berkeley (www.cbe.berkeley.edu).

REFERENCES

AIA (2014) *AIA/COTE Top Ten Green Projects.* American Institute of Architects. Available at: http://www2.aiatopten.org/index.cfm (Accessed 01/30/2014).

ASHRAE (2012) Handbook, HVAC Systems and Equipment. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA.

Babiak J, Olesen BW, Petras D (2009) *REHVA Guidebook no 7: Low Temperature Heating and High Temperature Cooling.* Federation of European Heating and Air-conditioning Associations, Belgium.

Bauman F, Feng JD, Schiavon S (2013) Cooling load calculations for radiant systems: Are they the same as traditional methods? *ASHRAE Journal*, 55, **12**, 14-20.

Bergische Universität Wuppertal (2013) *Net-Zero Energy Buildings - Worldwide.* Available at: http://batchgeo.com/map/net-zero-energy-buildings# (Accessed 01/30/2014).

CEN (2008) *EN15377: Heating Systems in Buildings-Design of Embedded Water Based Surface Heating and Cooling Systems.* European Committee for Standardization, Belgium.

Chen A, Leptoukh G, Kempler S et al (2009) Visualization of A-train vertical profiles using google earth. *Computers & Geosciences*, 35, **2**, 419-427.

Congress US (2007) *Energy Independence and Security Act of 2007.* Public Law, Session 110-140.

EnOB (2014) *Research for Energy Optimized Building.* Energieoptimiertes Bauen. Available at: http://www.enob.info/en/ (Accessed 01/30/2014).

Feng JD, Schiavon S, Bauman F (2013) Cooling load differences between radiant and air systems. *Energy and Buildings*, 65, **0**, 310-321.

GeoTABS (2011) *Database GeoTABS Cases - Towards Optimal Design and Control of Geothermal Heat Pumps Combined with Thermally Activated Building Systems in Offices.* The EraSME - GeoTABS Project. Available at: http://www.geotabs.eu/Database (Accessed 01/30/2014).

GreenSource (2014) *Green-Building Projects & Sustainable-Design Case Studies.* GreenSource. Available at: http://greensource.construction.com/green_building_projects/default.asp (Accessed 01/30/2014).

ISO (2012) *ISO11855: Building Environment Design - Design, Dimensioning, Installation and Control of Embedded Radiant Heating and Cooling Systems.* International Organization for Standardization, Switzerland.

Kalz DE. (2009) *Heating and cooling concepts employing environmental energy and thermo-active building systems for low energy buildings: System analysis and optimization* [Doctor of Philosophy] Technical University of Karlsruhe, Germany.

Kraak M (2004) The role of the map in a web-GIS environment. *Journal of Geographical Systems*, 6, **2**, 83-93.

Kwakkel JH, Carley S, Chase J et al (2014) Visualizing geo-spatial data in science, technology and innovation. *Technological Forecasting and Social Change*, 81, **0**, 67-81.

Miller CC (2006) A beast in the field: The google maps mashup as GIS/2. *Cartographica: The International Journal for Geographic Information and Geovisualization*, 41, **3**, 187-199.

Moe K (2010) *Thermally Active Surfaces in Architecture.* Princeton Architectural Press, New York, NY.

Mumma SA and Jeong J (2005) Direct digital temperature, humidity, and condensate control for a dedicated outdoor air-ceiling radiant cooling panel system. *ASHRAE Transactions*, 111, **1**, 547-558.

Olesen BW (2012) Using building mass to heat and cool. *ASHRAE Journal*, 54, **2**, 44-52.
Thornton BA, Wang W, Lane MD et al (2009) *Technical Support Document: 50% Energy Savings Design Technology Packages for Medium Office Buildings.* Pacific Northwest National Laboratory, Richland, WA.
Tian Z and Love JA (2009) Energy performance optimization of radiant slab cooling using building simulation and field measurements. *Energy and Buildings*, 41, **3**, 320-330.