

HEAT - HOME ENERGY ASSESSMENT TECHNOLOGIES: A WEB BASED SYSTEM FOR RESIDENTIAL WASTE HEAT ANALYSIS USING AIRBORNE THERMAL IMAGERY

B. Hemachandran, G. J. Hay*, C. D. Kyle, G. Chen and R. P. Powers

Department of Geography, University of Calgary, 2500 University Drive, Calgary,
AB, T2N 1N4, Canada, E-mail: gjhay@ucalgary.ca,

Convergence in Geomatics: Challenges and Opportunities The Role of Geomatics in Decision-Making: Providing Real Value to Canada's Economy and Society

KEY WORDS: TABI 320, Thermal Imagery, GEOgraphic Object-Based Image Analysis (GEOBIA), waste heat

ABSTRACT:

We report on the HEAT (Home Energy Assessment Technologies) pilot project conducted over the city of Calgary, Alberta, Canada and discuss plans for the 2010 full city implementation. The objective of HEAT is to provide free web tools to (i) evaluate and monitor residential thermal envelopes (i.e., waste heat) using a Thermal Airborne Broadband Imager (TABI), (ii) provide assessment information to individuals regarding their home's energy usage and savings, along with potential CO₂e (Carbon dioxide equivalent) footprint reductions, (iii) support Canadian urban energy efficiency programs. A demo version of this service can be accessed at <http://www.wasteheat.ca> (login: beta, pwd: beta). We welcome your constructive feedback.

1. INTRODUCTION

Since 1990, Canada has encouraged energy efficiency by implementing numerous incentive programs. For example, in Calgary Alberta, \$50 million was spent between 2003-2008 on energy performance programs to assess and upgrade city owned facilities, with an estimated \$7 million saved in energy costs per year and a reduction of ≈ 80 KT of CO₂ emissions (DEEAEP, 2010). The key for these savings was that *appropriate information provided action to enhance energy efficiency and reduce environmental impact* (Darby, 2006). But how do local home owners concerned with reducing their environmental footprint (in terms of both energy usage and emissions) know that their home – not the energy saving devices used inside it – is energy efficient?

Here we report on the goals, methods and results of the HEAT project (Kyle, 2009): namely to develop a *Geomatics turn-key solution* (software, hardware, data provision and web-portal /service) that will *freely* provide residents a way to automatically assess their home's thermal waste energy footprint (i.e., a detailed heat map of their home showing hot and cold areas), to identify where potential energy saving renovations could be made (i.e., windows, roofs, etc...) without the need for costly and potentially unnecessary in-situ thermal surveying taking place; and all as easily as clicking on Google maps. With this knowledge, home owners can participate in government grant/tax incentive programs to carry out energy saving renovations on identified areas, from certified service providers (Hay and Kyle, 2009).

2. STUDY AREA AND DATA COLLECTION

2.1 Study Area

The pilot project study area is located in the community of Brentwood, situated in the northwest of Calgary, Alberta,

Canada. This site encompasses 360 residential buildings, the majority of which were built between 1961 and 1965 – suggesting that they are good candidates for potential energy saving renovations.

2.2 Data Collection

A 600 x 2000 pixel TABI-320 geometrically corrected mosaic of the study area was provided by ITRES Research Limited, Calgary. The TABI-320 is a push broom thermal infrared sensor that produces an image 320 pixels wide. The sensor is sensitive to the 8 μ m - 12 μ m range of the electromagnetic spectrum and captures flight information that is later used to geo- and ortho-correct the imagery. The image was delivered in ENVI format with a spatial resolution of 1.0 m and a radiometric resolution of 0.1°C. A new larger area dataset will be acquired by the TABI-1800 during the spring of 2010. This new sensor is capable of collecting 1800 pixels per swath, effectively 5+ times the current capabilities of the TABI-320, in one fifth the time and cost (TABI, 2010).

3. METHODS AND RESULTS

3.1 System Architecture

HEAT is a Web 2.0 project developed primarily using Free and Open Source Software (FOSS). It uses OGC (Open Geospatial Consortium) compliant standards for geospatial and location based services. Python (a dynamic object-oriented programming language) is used for rapid development. PostgreSQL enabled with PostGIS is used along with Python to handle the geodatabase. IDL (Interactive Data Language) is used for image processing. Figure 1, shows the system components of HEAT.

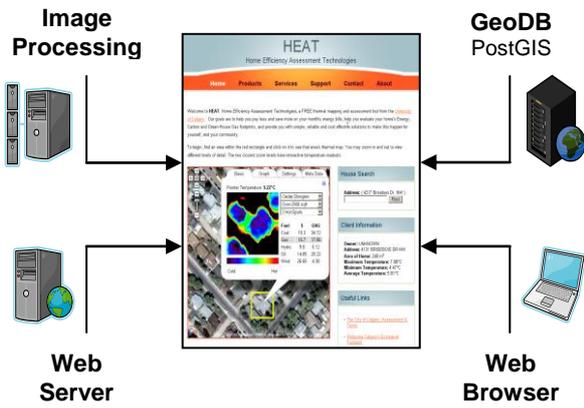


Figure 1: HEAT - System Components. *Note:* IDL is not FOSS; however, a GNU version (GDL) exists.

3.2 User Experience:

When first logged into the HEAT website, a smooth interpolated layer becomes visible. This layer provides an overall map of the area's waste heat distribution. As a user moves (i.e., mouse's) over the interpolated layer, different (pseudo) community boundaries appear. Once a community is clicked its corresponding waste information is displayed in the Community Waste Heat Information & Distribution section (Figure 2).

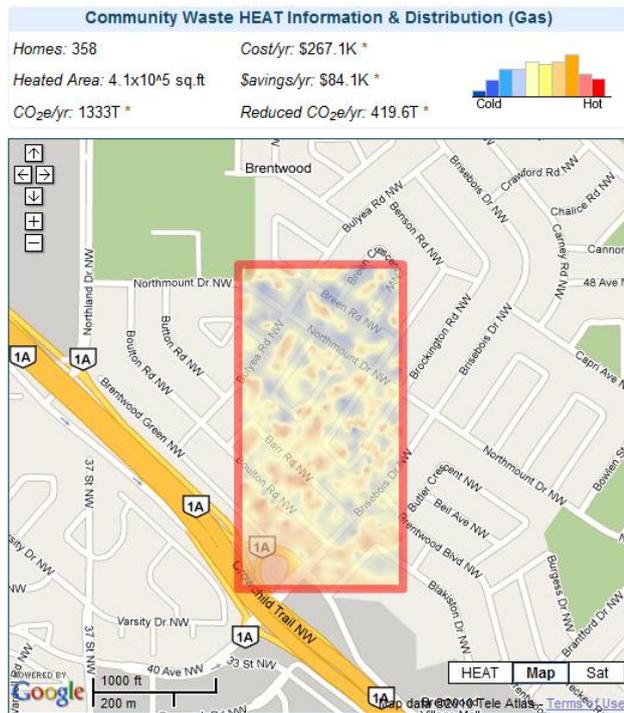


Figure 2: Interpolated waste heat layer for the full study site (red boundary) displayed using Google Maps with Waste HEAT Information and Distribution located above.

When a community is clicked, the map zooms in closer to that community's extent showing a more detailed HEAT map (Figure 3). The HEAT map is a house polygon layer classified into ten classes based on the average roof top temperature of all homes. When a house is clicked, a popup window appears

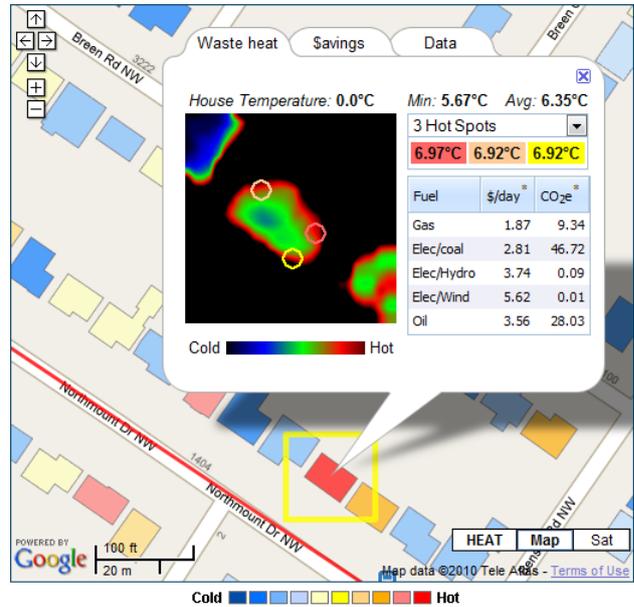


Figure 3: Popup window showing Minimum and Average roof temperatures. 3 Hot Spots (circles) pin-point their corresponding temperatures. The fuel table model shows different costs to heat this home for one day with different fuel types and their associated CO₂e (equivalent in kg/day).

This popup window contains the following information (i) a pseudo-coloured thermal image of the home, (ii) *Minimum* and *Average* roof top temperature, (iii) *3 Hot Spots* - showing the 3 hottest points on the roof, (iv) a *Fuel Table* - showing the cost of heating the home per day and their corresponding CO₂e (Carbon dioxide equivalent) in kg/day for various fuel types, and (v) a *Savings Tab*, that can be access in two ways: (a) by clicking on it or (b) by clicking on a fuel type in the fuel table. A click links to the *Savings Graph* (Figure 4) which displays the modeled cost (\$) and generated CO₂e for heating the house for a year. It also models the amount of savings (\$) and CO₂e reduced when the roof top temperature is reduced to the minimum temperature observed. These reductions may be achieved by increasing insulation, or improving roofing, windows, doors, other vents or the heating system. The Fuel Table and Savings Graph are based on models from The Urban Archetypes Project, a community case study for the City of Calgary (The Urban Archetypes Project, 2007).

A number of specific results and innovations unique to this project include the following: (1) The development of a new commercial waste-heat monitoring market for TABI sensors, (2) The development of automated/semi-automated *Geographic Object Based Image Analysis* solutions (i.e., GEOBIA tools/software) (Hay and Castilla, 2008) to generate GIS ready house polygons directly from airborne thermal imagery, rather than from pre-existing city cadastral datasets. This is critical when cadastral data are unavailable, thus allowing web accessible results within a week of data acquisition. (3) Monitoring may be applied yearly to provide evidence of successful Government EcoEnergy retrofit programs. (4) Multi-scale analysis can also be conducted ranging from individual homes to neighbourhoods, communities and cities, with opportunities to promote national and international intra- and inter-city heat waste competitions. (5) There is also potential to influence Calgary public energy-use by developing a web-enabled *Thermal Energy Index* as part of Calgary's public cadastral information. This will be similar to the walkability

index developed by Walkscore (<http://www.walkscore.com/>) which is used by millions.

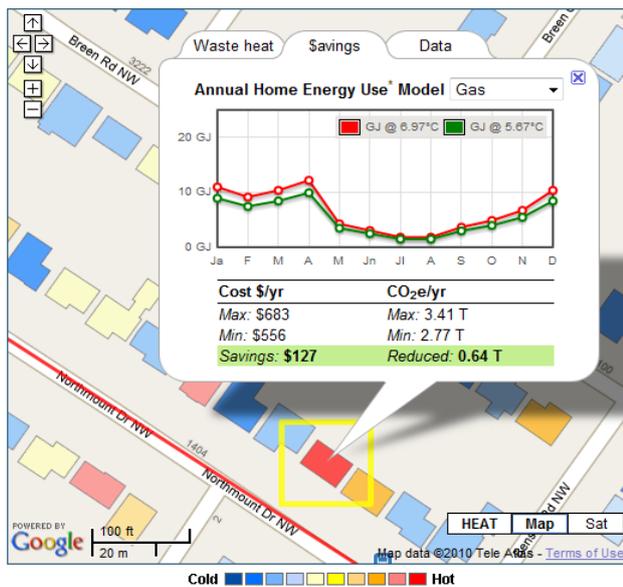


Figure 4: Savings graph showing savings in cost and reduced CO₂e.

4. DISCUSSION AND CONCLUSION

Based on location-aware web services and high resolution airborne thermal imagery, the HEAT pilot project presents a Geomatics solution with a high potential for commercialization and advanced spatial decision making, that are applicable through a range of scales from the individual home owner, the neighbourhood, the community, to an entire city (Hay et al, 2010). Based on the ease and ubiquity of internet access, we forecast this project to provide community, commercial, and environmental utility on a global basis while promoting Canadian excellence in Thermal Imagery and location-aware web services. To evaluate the current version of HEAT, please login as (*beta*) to (<http://www.wasteheat.ca>) with the password *beta* (no italics). Please note that this system is in continual development, so we invite you to provide us with your constructive comments and feedback and welcome collaborative opportunities and partnerships.

5. FUTURE WORK

The development of the new TABI 1800 sensor represents an opportunity to acquire thermal data over large city areas in less time, and at a lower cost than previous TABI sensors. This opens up possibilities to develop waste heat monitoring for the entire city of Calgary (25 x 35km), which can be used as a test bed for other cities world-wide. More accurate house energy models are being developed by exploring the relationship between roof top temperature and building construction.

6. ACKNOWLEDGEMENTS

We acknowledge the critical support from ISEEE (www.iseee.ca), ITRES Research Limited (www.itres.com), the City of Calgary (www.calgary.ca), the Urban Alliance (www.urban-alliance.ca), from Enmax Energy (www.enmax.com) and the UofC Foothills Facility for Remote

Sensing and GIScience (www.ucalgary.ca/f3gisci). The opinions expressed here are those of the authors, and may not reflect the views of their funding agencies.

References from Books:

Hay, G. J., and G. Castilla. 2008. *Geographic Object-Based Image Analysis (GEOBIA): A new name for a new discipline?* In: *Object-Based Image Analysis – spatial concepts for knowledge-driven remote sensing applications*. Eds: T. Blaschke, S. Lang, G. J. Hay. Springer-Verlag. Chapter 1.4, pp. 81- 92

References from Other Literature:

Hay, G. J. and Kyle, C. 2009. “Capturing City Waste Heat – Solutions and Applications.” Keynote to the City of Calgary Society of Professional Engineers Professional Development Day, May 20, 2009.

Hay G. J., Hemachandran, B and Kyle C.D, 2010. HEAT (Home Energy Assessment Technologies): Residential Waste Heat Monitoring, Google Maps and Airborne Thermal Imagery. Alberta, Canada. GIM International. Issue 03, Vol 24, March, pp 13-15.

Kyle, C. 2009. HEAT – Home Energy Assessment Technologies: A Web Service for Residential Energy Efficiency Evaluation in the City of Calgary. Unpublished MGIS Project, University of Calgary. April. pp 55.

References from websites:

Darby, S. 2006. The Effectiveness of Feedback on Energy Consumption. Report published by Environmental Change Institute. University of Oxford, pp 21. <http://www.eci.ox.ac.uk/research/energy/downloads/smart-metering-report.pdf> – last accessed April 18, 2010

Directory of Energy Efficiency and Alternative Energy Programs in Canada (DEEAEP). http://www.oee.nrcan.gc.ca/corporate/statistics/neud/dpa/policy_e/details.cfm?searchType=default§oranditems=all|0max=50&pageId=1&categoryID=all®ionalDeliveryId=all&programTypes=all&keywords=&ID=867&attr=0 – last accessed April 18, 2010

Hay G. J., Hemachandran, B and Kyle C.D, 2010. HEAT (Home Energy Assessment Technologies): http://www.gim-international.com/issues/articles/id1503-Home_Energy_Assessment_Technologies.html#reageer – last accessed April 18, 2010

TABI 1800 - http://www.itres.com/pdf/TABI1800_prod_sheet_2009.pdf – last accessed April 18, 2010.

The Urban Archetypes Project, Community Case Study: The City of Calgary, 2007. http://canmetenergy-canmetenergie.nrcan-rncan.gc.ca/fichier/80745/calgary_e.pdf - last accessed April 18, 2010.

Walkscore (<http://www.walkscore.com/>) – last accessed April 18, 2010