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FREE WASTE HEAT FOOTPRINTS

Home Energy Assessment Technologies

It is estimated that a quarter of the heat generated in our houses is lost through roofs. Replacement of the entire roof is too costly for most homeowners, who would prefer to carry out focused repair work. For this they need to know exactly where the roof is leaking. An in-situ thermal survey is expensive, and thus an unattractive option. *Home Energy Assessment Technologies*, or HEAT, represents software, hardware, data provision and web-portal service that enables free-of-charge, automatic assessment of domestic waste-heat footprints by simply clicking on their house in Google Maps. The authors present the results of a pilot project in Calgary, Alberta, Canada.

Since World War II, specialised heat sensors have recorded thermal infrared (TIR) energy for the purpose of acquiring surveillance information. Today TIR is routinely used for determining residential waste heat footprints. For example, during the winter of 2000 and 2007 the London Borough of Haringey (UK) conducted aerial TIR surveys to provide householders with evidence of energy (in)efficiency. In 2001 the city of Aberdeen in Scotland did the same, as did Exeter in 2009. Although an important start, these surveys produced simple temperature class maps, with limited capability for in-depth visual, statistical or location-specific analysis.

WASTED HEAT

Energy consumption behaviour changes dramatically only when individuals receive meaningful, dedicated feedback. Home Energy Assessment Technologies (HEAT) aims at providing Calgary waste heat data that is FREE, timely, in-depth, easy to use and location-specific for a wide range of private and governmental users. A full city airborne TIR survey (24km x 35km) will take place in early winter 2010, when the Thermal Airborne Broadband Imager (TABI-1800) becomes commercially operated. The current pilot project was developed using TABI-320 data over a smaller portion of Calgary.

TIR SENSORS

The TABI-1800, developed and manufactured by ITRES (1), a specialist in airborne hyperspectral remote-sensing sensor and software systems, has a swath width of 1,800 pixels, and ability to collect up to 175km2 per hour at 1m Ground Sample Distance (GSD). This is three to five times larger and faster than most other TIR sensors. The TABI-1800 calculates radiometrically calibrated and geo-referenced data when in the air and uses diffraction-limited optics to ensure spatial independence of each pixel to avoid smearing between pixels. The cooled detectors are four times faster than the non-cooled ones used in most TIR sensors, thus allowing for the rapid detection of much weaker thermal signals. Image quality can be further improved by acquisition at 50cm GSD or smaller. Since the TABI-1800 will only become operational after February 2010, we have used a 2004 TABI-320 mosaiced scene to develop and test the Web 2.0-enabled HEAT

Figure 1, The project is based in Calgary, Alberta, Canada.

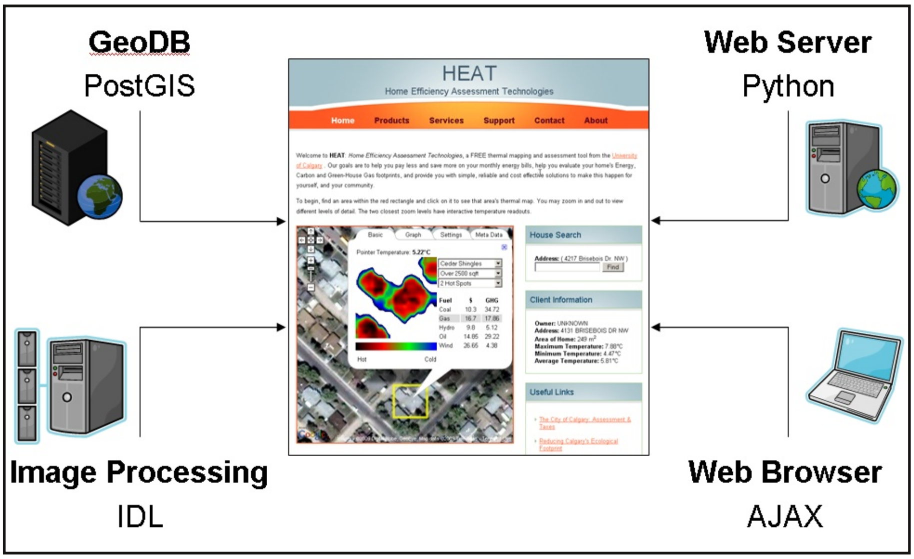


Figure 2, Four components of HEAT depicted in the corners and arranged around the home page.

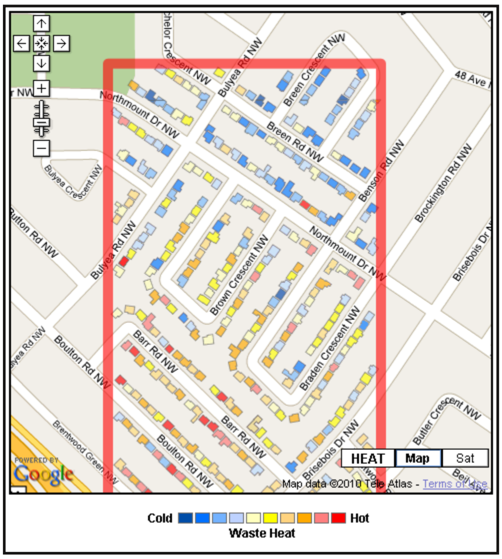


Figure 3, Portion of Residential HEAT Map: (red rectangle) extent of data collected by two mosaiced TABI 320 flightlines, width 600m.

protocols. The ITRES TABI-320 is a pushbroom scanner with 320 pixels in-line that is able to acquire data in the 8µm-12µm portion of the electromagnetic spectrum.

STUDY AREA

Our study site consists of 600 x 2,000 geo-referenced pixels (1m GSD and a 0.1°C radiometric resolution) that cover 358 dwellings in the Brentwood community of Calgary in Alberta, Canada (see Figure 1). These houses were built between 1961 and 1965, when concepts of *environmental impact and green-house-gas (GHG) footprint* were unfamiliar.

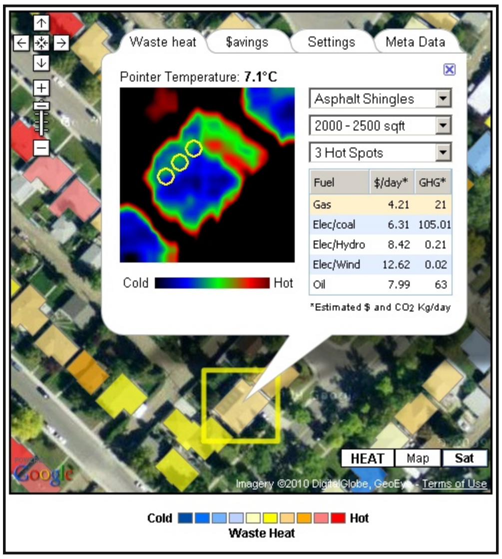
SYSTEM ARCHITECTURE

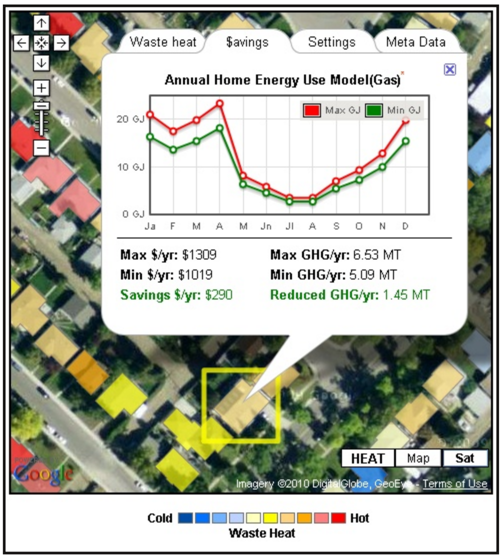
The architecture is based on Open Geospatial Consortium (OGC) standards, and its four components are shown in Figure 2. A combination of PostgreSQL and PostGIS provides the geospatial database. Open-source geospatial libraries such as GDAL/OGR are used for raster and vector file handling, and PROJ.4 for coordinate system conversion in the image processing pipeline and by the geospatial database itself. Python is used for rapid program development, and the results are projected onto Google Maps. Image processing is conducted using ENVI and IDL, both software products from ITT Visual Information Solutions. The extraction of houses is done with a combination of in-house and commercial *Geographic Object-based Image Analysis* (GEOBIA) software (see feature by Addink in GIM International January 2010) applied to TABI data and City of Calgary cadastral datasets that include outlines of houses. The system currently generates three maps (*Community, Residential and Home*) enabling multi-scale analysis ranging from individual houses to neighbourhoods, communities and cities, with the potential to promote waste-heat competitions at city, inter-city, national and international levels. Two related energy models are also generated: *Fuel Table Model* and *Annual Home Energy Use Model*.

Regular TIR capture enables adjusting effectiveness of renovations

FOCUSED REPAIRS

On entering the site the user sees a *Community HEAT Map* overlaid on Google Maps, representing a continuous waste-heat surface defined within the civic boundaries of each community. This surface is created through an interpolation of the average roof top temperatures of each house, which are differentiated according to ten classes, from cold (blue) to hot (red). This scale allows evaluation of multiple communities at a glance. The top thousand-plus hottest houses in an area can also be identified. The percentage of houses per class for each community are dynamically graphed by mouse movements, enabling planners to evaluate and compare communities, for example, sponsoring energy-saving retrofit incentives for communities with high heat loss. Clicking on a specific community produces a more detailed *Residential HEAT Map* consisting of outlines of houses to which one of the above ten classes are assigned (see Figure 3); this enables detailed comparison of houses within a neighbourhood. By clicking on a house, the *Home HEAT Map* appears, showing data captured by the TIR sensor (Figure 4). The three hottest locations (hot spots) of individual houses are automatically defined by yellow circles when the user selects this





option, paving the way for savings by focused repair. For example, in Figure 4 the yellow circles appear above four skylights, suggesting to the owners that they might check and repair these weaker parts of the roof. Post-renovation they will be able to verify the effectiveness of their efforts once free TIR data becomes available at some future date.

ENERGY MODELS

The Graphical User Interface (GUI) allows the user to inform the system about roof material, so that it can automatically determine the material's emissivity: a measure of a material's ability to radiate absorbed energy. Two objects of the same temperature will not show the same temperature in a TIR image if their emissivity differs. Translating emissivity as recorded by the TIR sensor into temperatures allows accurate and house-specific energy modelling: a unique feature of HEAT. Moving the mouse makes temperatures pop-up in place of TIR sensor data. The GUI also enables retrieval of house area from city cadastral data, along with minimum, maximum and average home temperatures. It is also possible to define the Fuel Table Model: an energy model used to estimate GHG generation and cost per day of heating to maximum defined roof temperature using several types of fuel. In the completed HEAT system, fuel types and costs will be geographically defined. Movements of the mouse will dynamically highlight fuel sources (Figure 4). Double clicking will prompt a pop-up of the corresponding *Annual Home Energy Use Model* for the defined fuel type (Figure 5). This second energy model estimates total monetary and GHG costs and savings per year for each house, based on heating to the maximum and minimum defined temperatures.

CONCLUDING REMARKS

Regular TIR capture of the same area, annually for example, enables adjusting the effectiveness of renovations. You are invited to login to www.wasteheat.ca as beta, with password beta to evaluate the system.

ACKNOWLEDGEMENTS

Thanks are due to Gang Chen.

MORE INFORMATION

1 www.itres.com
2 www.wasteheat.ca
3 canmetenergy.nrcan.gc.ca
4 calgary.ca/docgallery/BU/planning/pdf/plan_it/energy_mapping_study.pdf

▲ *Figure 4, Home HEAT: (inset) generated from TABI 320 data; $/day and GHG estimated from different fuel sources; three yellow circles (located, in this example, over 4 skylights) indicate hot spots*

▲ *Figure 5, Annual Home Energy Use Model for house in yellow rectangle at bottom illustration.*

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