Technology Assessment of Greenhouse Gas and Carbon Emissions Management Strategic Planning Tools – Localized Strategic Planning

For
The U.S. Department of Energy
National Energy Technology Laboratory

Under
Contract Number: DE-AM-26-99FT40465
Task 50113, Subtask 3

Augusta Systems Report Number:
AS-NETL-50113-3-FR

December 31, 2002

AugustaSystems

Research Ridge - 3606 Collins Ferry Road, Suite 202 - Morgantown, WV 26505
T. 304.599.3200 www.augustasystems.com F. 304.599.3480

DISCLAIMER AND ACKNOWLEDGEMENTS

Disclaimer

Acknowledgements

This report was prepared by Augusta Systems, Inc., as a member of the Concurrent Technologies Corporation's Program, Product, and Project Engineering and Analysis (P3EA) Team, providing services to support the United States Department of Energy (USDOE) National Energy Technology Laboratory (NETL) Carbon Sequestration Product Line. General information regarding this publication may be obtained from the USDOE/NETL Task Monitors, Sarah Forbes at (304) 285-4670, and Sean I. Plasynski at (412) 386-4867. Specific questions regarding the report should be directed to the project team at (304) 599-3200. Contributing authors to this report were Michelle L. Varga, Janet M. Wood, and Patrick R. Esposito II. Assistance with technical research and final editing were provided by C. David Locke and Patrick R. Esposito. Additional technical writing and editorial assistance was provided by Carrie Pancake.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

International, national, and local measures are being assessed and implemented that could aid in the reduction and concentration of greenhouse gas (GHG) emissions and, most significantly, carbon emissions. To meet these regulations and objectives, public policy makers and corporate decision makers must examine cost-effective strategies to approach the legion of options for GHG emissions management, including project-based applications involving carbon sequestration facilities, landfill gas-to-energy sites, and others. Another option that exists to aid enterprises in meeting these regulatory demands and voluntary objectives is the emerging global market in GHG emissions trading.

To achieve cost-effective transactions in this market and through internal or cooperative projects, an enterprise must use a logical, systematic, and informed process. Otherwise, the enterprise will risk implementing GHG emissions reduction strategies which may not be cost-effective. Likewise, public bodies, which will create the policies to drive the use of the emerging trading market and initiation of emissions reduction projects, must approach policy development with a holistic and organized method.

Thus, public bodies and industry leaders must be able to design policy and business strategies to achieve optimal outcomes when fashioning approaches to GHG emissions management, including those focused on market-based solutions.

One element to consider in GHG emissions management strategic planning is the role of localized planning. The linkages between GHG emissions, global climate change, and localized climate change merit in-depth examination. This report concentrates on the urban heat island (UHI) effect, which is one type of localized climate change and its relationship to GHG emissions through the identification UHI mitigation strategies that could potentially also reduce GHG emissions.

INTRODUCTION

When examining GHG emissions management strategic planning many factors must be considered such as the relationship of GHG emissions management strategic planning to industry, state governments, and local governments. This report focuses on the opportunities for strategic planning at the local level.

As GHG emissions are studied for linkages to global climate change, the impacts of localized climate effects merit consideration because of common connections. One type of localized climate change is that of the urban heat island (UHI). This term describes an effect borne of growth and development of major urban areas over the past few decades. This effect is important to consider in examining strategic planning for GHG emissions by public entities because the UHI effect may, in fact, be strongly correlated in many ways to global climate change borne of GHG emissions.

While UHIs and global climate change are two distinct phenomena, they are related. The presence of elevated urban temperatures does not directly imply that global climate change is occurring. These increased urban air temperatures are believed to be the result of urban development, not global climate change. The mechanism that connects the UHI effect to global climate change is that of increased energy demand. As certain urban temperatures increase due to the UHI effect, more electric power is required for residential and commercial indoor air conditioning and other cooling purposes. As fossil fuel power plants generate electricity to meet this increased demand, GHGs and other emissions increase, in turn. Just as UHIs caused increased GHGs, mitigation of UHIs and reductions of GHGs are also interrelated as decreased UHI effects can result in decreased energy demand and decreased GHG emissions. In addition, urban landscaping projects, like urban tree projects, may be able to play a dual role where these projects offer UHI mitigation benefits and GHG emissions offsets.

The following sections will provide a general overview of UHIs and information on the relationship between UHIs and GHGs. These sections are provided as background material to illustrate the need for GHG emissions strategic planning tools for public bodies to factor in localized climate change issues as they complement GHG emissions reduction and offset activities geared to mitigating global climate change.

2.0 Urban Heat Islands (UHIs)

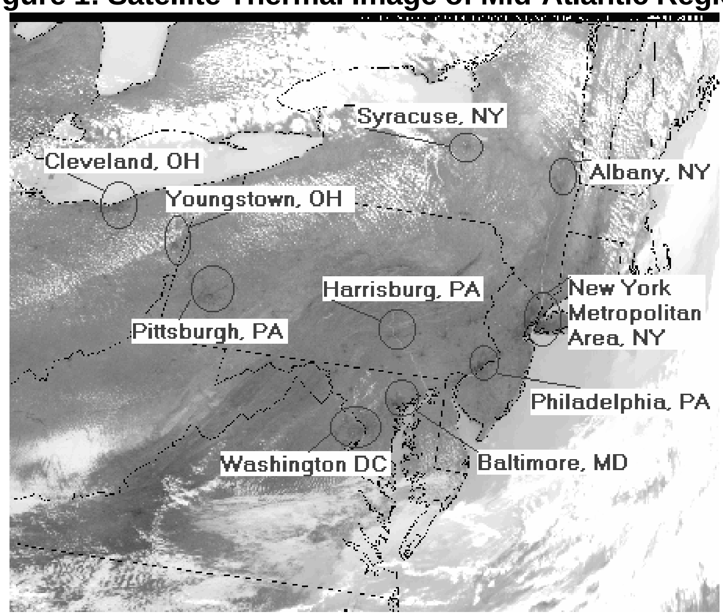
2.1 Overview

The UHI can be described as an urban area, which compared to the suburban and rural surrounding areas, records higher air temperatures. On a thermal map, the urban area appears as an isolated island due to the variation in heat signatures, thus providing the impetus for the UHI term. The variation in heat from the interior of the city to the surrounding rural areas has been known to range from 5 degrees Fahrenheit (°F) to over 10 °F.

The UHI effect has been tied to changes in regional weather patterns such as heat waves, droughts, and flooding. These results occur when the temperature of the interior of the city rises, and low air pressure is created, initiating the rush of colder, dense air from the surrounding areas into the urban center. The complex geometry of the skyscrapers and tall buildings within the heart of the city enhances the upward draft of the incoming artificial wind. The rush of warm air upward triggers the unusual occurrence of isolated convective thunderstorms. These thunderstorms serve two purposes, to cool the city and to remove airborne pollutants. A disadvantage to the convective thunderstorms is the threat of localized flooding due to the lack of water absorbing vegetation within the city, and the use of non-porous construction materials.

The figures below illustrate visual and thermal maps of selected areas of the U.S. The regional thermal map shown in Figure 1 was taken utilizing satellite imaging technology, the Advanced Very High Resolution Radiometer (AVHRR), owned by the United States Geological Survey (USGS). The imaging technology depicts warmer masses by depicting an enrichment of color, while colder areas such as cloud tops are depicted by lighter shades. Major urban areas within the District of Columbia and the states of Maryland, New York, Ohio, and Pennsylvania are identified in Figure 1.

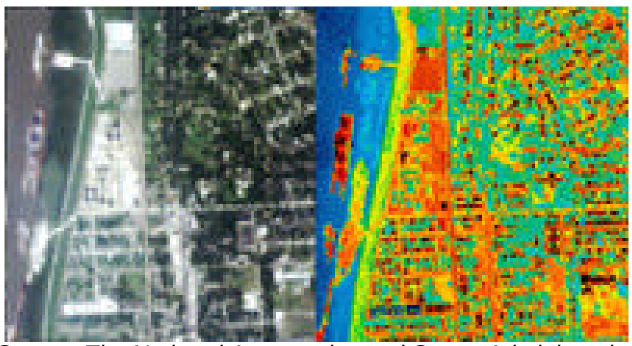
Figure 1: Satellite Thermal Image of Mid-Atlantic Region



Source: United States Geologic Survey thermal image obtained from the University of Wisconsin-Madison. (Ackerman)
Note: Urban designations added by Augusta Systems research team.

Figure 2 represents a side-by-side visual (left) and thermal (right) images of a selected UHI within the U.S. – Baton Rouge, Louisiana. This city was among those chosen to participate in UHI mitigation demonstration projects under the Urban Heat Island Pilot Project (UHIPP), a project mainly financed by the USEPA. In the Figure below, the presence of yellow and red areas signify intense heat, and generally correspond with roads and buildings, while the blue and green areas are comparatively cool and generally indicate regions of water and vegetation.

Figure 2: Baton Rouge, Louisiana Visual and Thermal Images



Source: The National Aeronautics and Space Administration Marshall Space Flight Center. (Dooling)
Note: Visual image appears on left and thermal image on right.

As depicted by the thermal images, the local urban environment has the capability to modify the conditions in the atmospheric boundary layer – the thin air stratum above the ground. As the urbanization of a city progresses, especially in the case of urban sprawl, the once natural landscape becomes overwhelmingly developed on a commercial, industrial, and residential scale.

2.2 Causes and Effects

Researchers have linked contributions to the UHI effect to three known causes associated with urban development and growth:

(1) Construction practices (building architecture, construction materials, and urban planning);
(2) Loss of vegetation (clearing of land for construction and negligible re-vegetative efforts); and,
(3) An increase in pollutant emissions (mainly an increase in ground-level ozone formation and airborne black carbon particulate matter).

As construction practices do not directly correlate to GHG emissions, this section will not focus on this cause, but instead will principally focus on the causes of UHIs that are related to GHG emissions reduction – loss of vegetation and increased pollutant emissions.

UHIs form as vegetation is replaced by asphalt and concrete for roads, buildings, and other structures necessary to accommodate growing populations. Plants and trees have a natural cooling ability that enables them to transpire large amounts of water from the surface of their leaves and evaporate the water into the atmosphere from the air and sunlight absorbed by the leaves. This process is referred to as evapotranspiration. The absorbance of solar radiation by the leaves and the evaporation of water into the atmosphere aids in reducing the ambient temperature in the urban area. It is this natural cooling ability of vegetation that makes it such a significant combatant against the UHI effect. Thus, the displacement of trees and shrubs increases the UHI effect by eliminating the advantageous cooling mechanism of evapotranspiration and causing an increase in the incoming solar radiation due to a lack of shade.

City growth results in the development of lands surrounding the heart of the city and stimulates growth in the city population. An increase in population directly relates to an increase in housing development, commercial development, and vehicles within the confined area of the city. This growth, either controlled or uncontrolled, will result in the loss of vegetation attributed to clearing of land, new building and road construction, and an increase in pollutant emissions. Just as significantly, this loss of vegetation likely eliminates plants and ground cover vegetation, which had played a key role in absorbing carbon dioxide from the atmosphere and historically contributed to the offset of GHG emissions.

The prominent air quality pollutant contributor associated with the urbanization of cities and the UHI effect is black carbon emissions from non-nuclear power generation facilities. Current research of weather patterns within and surrounding UHIs has led to the discovery that black carbon particulate matter released from industrial facilities, motor vehicles, and other combustion activities plays a greater role in enhancing the UHI effect than initially believed. When incomplete combustion of a carbon-based fuel (i.e. coal, diesel fuel, bio-fuels) occurs, black carbon particulate matter, or airborne ash, is produced. Black carbon has been correlated to the UHI effect due to the ability of the individual particles to absorb solar radiation and convert it to heat energy, while being suspended in the air. If large concentrations of black carbon particles are suspended in the air, then the air is heated at a faster rate, leading to a stimulation of the UHI effect.

Research performed in China by the National Aeronautics and Space Administration (NASA) and the National Science Foundation (NSF) has led to the conclusion that black carbon particulate matter is a main contributor to recent temperature and precipitation changes in China. Emissions of black carbon particulate matter are greater in China and India since the common fuels used for cooking and heating are wood, field reside, cow dung, and coal. Since cooking and heating are low combustion temperature activities, incomplete fuel combustion occurs, which leads to an increase in black carbon particulate emissions.

Although the cooking and heating fuels commonly used in households in the U.S. and Europe are not wood, cow dung, or coal, this does not exempt these countries from examining the impact of releasing black carbon particulate matter into the atmosphere. Markedly, as a city grows in population, the number of motor vehicles within the urban area also increases. Since black carbon particulate emissions are commonly generated by the start-stop traffic conditions of urban vehicular traffic, the increase in motor vehicles contributes to the UHI effect by releasing an increased amount of black carbon particulate matter into the surrounding air from vehicle exhaust.

In Europe, a major strategy to curb GHG emissions, most notably carbon dioxide, is to promote the use of diesel fuel instead of gasoline fuel motor vehicles. The rationale for this promotion is that diesel fuel powered motor vehicles obtain 25 percent to 35 percent better gas mileage and emit less carbon dioxide than similar motor vehicles utilizing gasoline fuel; however, motor vehicles powered by diesel fuel are capable of emitting 25 to 400 times more black carbon particulates and other organic matter per mile. When considering urban vehicular traffic, diesel engines actually emit greater amounts of black carbon particulate matter, thereby potentially increasing the opportunity for UHIs to emerge. This relationship is just one of the many associations between UHIs and GHGs.

3.0 Relationship of UHI Mitigation and GHG Emissions Reduction

UHIs are a global issue and are recognized nationally and internationally as an environmental challenge that can benefit from short-term successes through mitigation efforts. UHI mitigation efforts will, in effect, aid in the reduction of energy consumption and the release of associated GHGs.

Current mitigation strategies tend to promote the transition from low albedo[1] construction materials to high albedo construction materials, as well as the enhancement of vegetation through landscape projects, green roofing projects, and the establishment and enforcement of tree ordinances. These vegetation enhancement projects, like urban tree projects, can, through proliferation of plants and other vegetative cover, play a key role in carbon dioxide absorption, and, thereby serve to offset GHG emissions.

Table 5 below illustrates information concerning the annual energy savings, avoided peak power, and associated carbon dioxide reductions in the UHIPP metropolitan areas. The metropolitan area which most benefited from the UHIPP is Houston, Texas, which reduced the annual carbon dioxide emissions associated with avoided peak power energy consumption by approximately 159 kilotons.

Table 1: UHIPP Metropolitan Areas Energy Savings (Direct and Indirect)

Metropolitan Area	Population (in thousands)	Annual Energy Savings (in $ Million)	Peak Power Avoided (in Megawatts)	Annual Carbon Reductions (in kilotons)
Baton Rouge, LA	500	15	129	34
Chicago, IL	8000	29	386	53
Houston, TX	4000	79	700	159
Sacramento, CA	1500	29	423	49
Salt Lake City, UT	1100	4	80	7

Source: Lawrence Berkeley National Laboratory energy savings reports, with rounded statistics. It is important to note that local average 1997 electricity and natural gas prices were used Baton Rouge, Sacramento, and Salt Lake City, while 1999 electricity prices and 2000 natural gas prices were used for Chicago and Houston. (Wong, The U.S. Environmental Protection Agency's Heat Island Reduction Initiative (HIRI) Status and Future Directions Presentation.)

This table illustrates the inherent value in local strategic planning to mitigate UHI effects, as it can truly impact GHG emissions reduction efforts in a very positive manner. However, in order to fully benefit from these opportunities, urban planners must possess the appropriate technologies to devise these strategies and account for their benefits. At present, there is a need to develop technologies to meet these local planning needs, just as there are needs to develop new technologies to assist with state government and industry planning.

[1] Albedo can be defined as the proportion of light reflected by a surface.

4.0 CONCLUSION

Based upon this research effort, Augusta Systems has concluded that localized planning efforts are important to the both mitigate UHI effects and minimize GHG emissions. In order to properly assess the opportunities and consequences derived from local regulations and decisions, educational and planning tools must be developed to assist local planning, by both public and private parties, regarding UHI effect and GHG emissions reductions.

REFERENCES AND RESOURCES

Specific References and Resources

Ackerman, Steve. “Urban Heat Island.” University of Wisconsin-Madison. 18 November 2002. <http://cimss.ssec.wisc.edu/wxwise/heatisl.html>.

Anderson, Margot. “Revising DOE’s Voluntary Greenhouse Gas Reporting Program Presentation.” The U.S. Environmental Protection Agency Fifth State and Local Climate Change Partners Conference. 22 November 2002.

Boice, Daniel. “The Heat Is On.” Southwest Research Institute. Fall 1997. 18 November 2002. <http://www.swri.edu/3pubs/ttoday/fall97/heat.htm>.

“California Climate Action Registry Certification Protocol.” California Climate Action Registry. October 2002. 15 November 2002. <http://www.climateregistry.org/files/certification_protocol_102102.pdf>.

“California Climate Action Registry General Reporting Protocol.” California Climate Action Registry. October 2002. 15 November 2002. <http://www.climateregistry.org/files/general_reporting_protocol_102102.pdf>.

Chohan, Rani, Robert J. Gutro, Caroline Ladhani and David E. Steitz. “Black Carbon Contributes to Droughts and Floods in China.” National Aeronautics and Space Administration. 26 September 2002. 18 November 2002. <http://www.gsfc.nasa.gov/topstory/20020822blackcarbon.html>.

“Comparing Cost Estimates for the Kyoto Protocol.” United States Department of Energy, Energy Information Administration. 1 October 2002. <http://www.eia.doe.gov/oiaf/kyoto/cost.html>.

“The Diesel Fuel Excise.” Nuclear Information Center (Australia). July 1999. 13 November 2002. <http://www.ccsa.asn.au/nic/SustDev/diesel.htm>.

Dooling, Dave. “Cities Getting Ready for Next Heat Wave.” National Aeronautics and Space Administration. 20 November 1998. 18 November 2002. <http://science.nasa.gov/newhome/headlines/essd20nov98_1.htm>.

“Emissions of Greenhouse Gases in the United States, 2000.” United States Department of Energy, Energy Information Administration. 1 November 2001. 4 October 2002. <http://www.eia.doe.gov/oiaf1605/1605a.html>.

“Global Warming: Actions: Local: Heat Island Effect.” United States Environmental Protection Agency. 8 October 2002. 22 November 2002. <http://yosemite.epa.gov/OAR/globalwaring.nsf/content/ActionsLocalHeatIslandEffect.html>.

"Global Warming—Climate." United States Environmental Protection Agency. 31 October 2002. 2 December 2002. <http://yosemite.epa.gov/oar/globalwarming.nsf/content/climate.html>.

Heilprin, John. "Study Says Black Carbon Emissions in China and India Have Climate Change Effects." Environmental News Network. 27 September 2002. 18 November 2002. <http://www.enn.com/news/wire-stories/2002/09/09272002/ap_48549.asp>.

Leifert, Harvey. "Despite Lower Carbon Dioxide Emissions, Diesel Cars May Promote More Global Warming Than Gasoline Cars." National Aeronautics and Space Administration. 21 October 2002. 11 November 2002. <http://earthobservatory.nasa.gov/Newsroom/MediaAlerts/2002/2002102110865.html>.

Loreti, Christopher, William Wescott, and Michael Isenberg. "An Overview of Greenhouse Gas Emissions Inventory Issues." Pew Center on Global Climate Change. August 2000. 1 October 2002. <http://www.pewclimate.org/projects/greenhouse.pdf>.

"President Announces Clear Skies & Global Climate Change Initiatives." Office of the President of the United States. 14 February 2002. 15 October 2002. <http://www.whitehouse/gov/news/releases/2002/02/20020214-5.html>.

Rabe, Barry. "Greenhouse and Statehouse: The Evolving State Government Role in Climate Change." Pew Center on Global Climate Change. November 2002. 1 December 2002. <http://www.pewclimate.org/projects/states_greenhouse.pdf>.

Roth, Steve. "Cleaning the Air." Energy Markets. September 2002: 41-44.

Sailor, David. "The Urban Heat Island: Causes, Impacts, and Potential for Mitigation Presentation." The U.S. Environmental Protection Agency Fifth State and Local Climate Change Partners Conference. 21 November 2002.

Shepherd, Marshall, J. "What is an Urban Heat Island and How Does It Affect the Global Water Cycle?" National Aeronautics and Space Administration. 4 October 2002. 18 November 2002. <http://www.gsfc.nasa.gov/scienceques2002/20021004.htm>.

"State and Local Climate Change Program – Partnerships and Progress: 2001." United States Environmental Protection Agency. 2001: 19-28.

"Team Probes Atlanta Heat Island." Environmental News Network. 24 April 1999. 18 November 2002. <http://www.enn.com/enn-news-archive/1999/03/032499/heatisland_2295.asp>.

Wong, Eva. "Strategies to Reduce Urban Heat Islands Presentation." The U.S. Environmental Protection Agency Fifth State and Local Climate Change Partners Conference. 21 November 2002.

Wong, Eva. "The U.S. Environmental Protection Agency's Heat Island Reduction Initiative (HIRI) Status and Future Directions Presentation." City of Toronto. 3 May 2002. 22 November 2002. <http://www.city.toronto.on.ca/taf/cleanairpartnership/pdf/uhis_wong.pdf>.

General Resource Websites

<http://thomas.loc.gov>.
<http://unfcc.int>.
<http://www.cckn.net>.
<http://www.climateark.org>.
<http://www.climateregistry.org>.
<http://www.eia.doe.gov>.
<http://www.eia.doe.gov/oiaf/1605/background.html>.
<http://www.eia.doe.gov/oiaf/1605/database.html>.
<http://www.emissions.org>.
<http://www.enn.com>.
<http://www.epa.gov/airmarkets/trading/>.
<http://www.fe.doe.gov>.
<http://www.gnet.org>.
<http://www.ieta.org>.
<http://www.ipcc.ch>.
<http://www.netl.doe.gov/coalpower/sequestration/index.html>.
<http://www.pewclimate.org>.
<http://www.planetark.org>.
<http://www.platts.com/features/emissions/>.
<http://www.unep.ch>.