CHAPTER I

INTRODUCTION

Rationale for the study

Urban areas around the world are experiencing rapid population growth, urban sprawl and long commuting distances. Forests and open spaces covered with low natural vegetation are being replaced by residential buildings. As a result, solar energy is absorbed by concrete and paved surfaces, causing the surface temperature of urban structures to become several degrees higher than ambient air temperatures. As surfaces become warmer, overall ambient temperature increases, see figure 1.

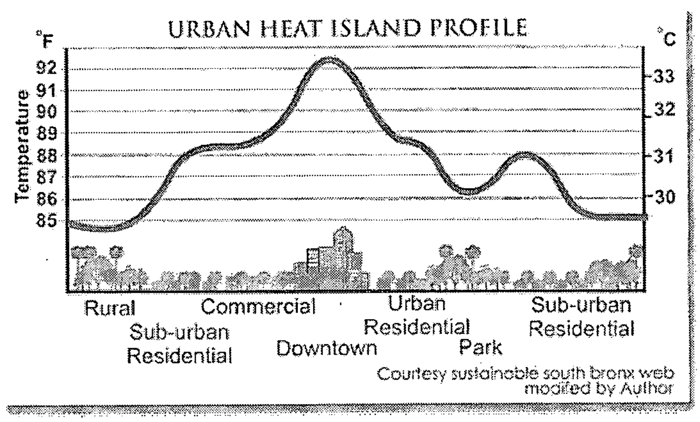

Figure 1 urban heat island profile [1]

This phenomenon, called ''urban heat island'', has the effect of increasing the demand of energy, accelerating the formation of harmful smog and causing human thermal discomfort and health problems by intensifying heat waves over cities [1, 2, 3]. Urban heat island contributes to global warming and affect human health and although urban heat islands are distinctly different from the phenomenon of climate change, during the summer months they can contribute to global warming. The increased use of air conditioning and refrigeration needed to cool indoor spaces in a heat-island city, for example, results in the release of more of the heat-trapping greenhouse gases that cause global warming. Furthermore, the poor air quality that results from this increased energy usage can affect our health, aggravating asthma and promoting other respiratory illnesses.

Urban heat island is the mutual response of many factors which could broadly be categorized as controllable and uncontrollable factors as shown in figure 2. The controllable and uncontrollable factors could further be categorized as the temporary effect variables, such as air speed and cloud cover, permanent effect variables such as green areas, building material, and sky view factor and cyclic effect variables such as solar radiations and anthropogenic heat sources. The heat generated and contained in an area comes from the sun in the form of solar radiations and from power plants, automobiles, air-conditioners and other sources as anthropogenic heat. Almost all anthropogenic heat enters into the environment instantly and directly. On the other hand, only part of solar radiations heat up the environment directly, the rest are absorbed by the complicated urban built structures and heat up the environment indirectly. The basic heat transfer and energy conservation processes, such as conduction, convection and radiation play their characteristic roles in this heat exchange. The structures on ground level, such as walls and roof facets, irrigated gardens, non-irrigated green spaces, lawns and paved areas etc. capture solar radiation to different extents. These natural and man-made structures continuously absorb and store this radiation in the form of heat energy from sunrise till late afternoon. Afterwards, the sun starts setting aside and the environment starts cooling down. The heat energy stored in structures is then released to the environment. The method and quantity of heat released by the urban structures, however, depends on other controllable factors such as the sky view factor and building material. In a typical urban area, massive construction material is placed within a very small space that captures high intensity of solar radiation. The ability of heat release by long-wave radiation in cities is low due to decreased sky view which results in high heat storage in building structures. It is believed that the albedo, the reflected light in comparison to the incident light, is also very low in cities due to typical street canyon configurations, and is one of the main reasons of high air temperatures.

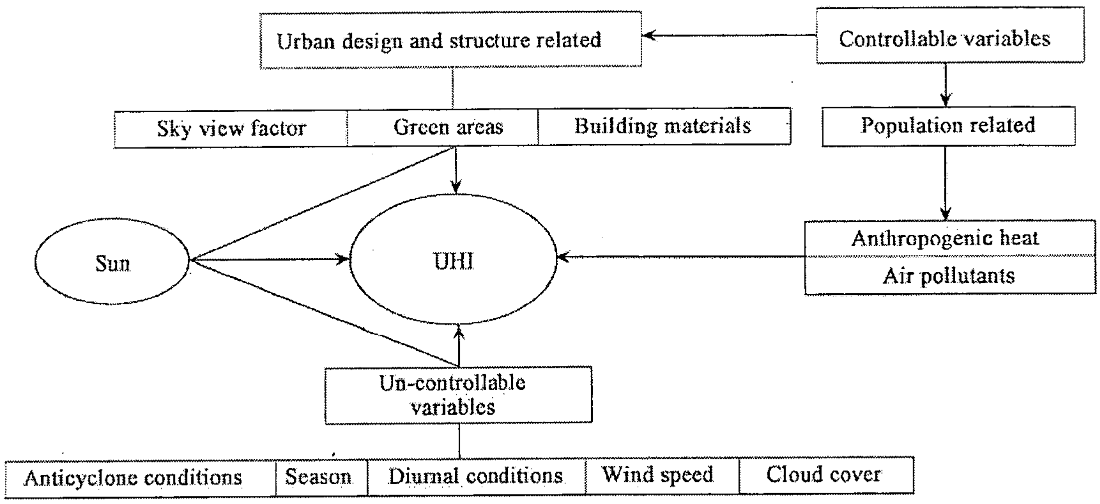

Figure 2 Generation of urban heat island (UHI) [3]

Electricity consumption comprises different variables of diverse nature. The variables might be due to technology, climate, or human activities. On the one hand, there are physical characteristics of the actual households and the electric devices they handle, mainly the air conditioning consumed. And, on the other hand, there is the behavior of the residents in regards to the use of electric power inside their homes, a factor which can be associated to their income level and the life style of each of the families. The demand for this energy is expected to grow rapidly throughout the world, particularly in developing countries. The growing demand of electricity will definitely put enormous pressure upon the upstream sources of energy such as petroleum fuels and natural gas. Over the past few decades, it has been observed that there is an increasing concentration of these greenhouse gases (GHGs) that have harmful impacts on the environment. In particular, CO_2 is the significant by-product that stems from the burn of these fuels used to generate electricity in conventional power plants. By the way, for the electricity generation in Thailand has portion of various energy consumption that has acquired from the electrical power station of each unit and the types of fuels.

In order to reduce heat gain into buildings, which is one of the crucial causes of heat island effect, this study aims to develop solar reflectance and emittance of house paint. The term solar reflectance (SR) designates the total reflectance of a surface, considering the hemispherical reflectance of radiation, integrated over the solar spectrum, including specular and diffuse reflection. The infrared emittance (ε) specifies how well a surface radiates energy away from itself as compared with a black body operating at the same temperature. These two properties mainly affect the temperature of a surface. Increasing either reflectance and/or emittance lowers a surface's temperature, which in turn decreases the heat penetrating into the building, if it is a surface of the building envelope, or contributes to decrease the temperature of the ambient air as the heat convection intensity from a cooler surface is lower.

Mitigation of the heat island effect can be achieved by the use of cool materials. Cool materials are new complex inorganic color pigments that exhibit dark color in the visible spectrum and high reflectance in the near infrared portion of the electromagnetic spectrum. The new pigments increase the near infrared reflectance of exterior paints, thereby dropping the surface temperatures (reducing heat gain) of roofs and walls, which, in turn, reduce the cooling-energy demand of the building. However, determining the effects of climate and solar exposure on the reflectance and the variability in color over time is of paramount importance for promoting these energy efficiency benefits.

Statement of the problem

Rising energy costs continue to drive advances in new technologies designed to improve energy efficiency. One such technology is the use of specialty chemical with high solar reflective property used to impart color to an object, and reflect the invisible heat from the object to minimize heat build-up, when exposed to solar irradiance. Ultimately, the reflection of solar energy lowers the heat build-up resulting in a reduction on the load of the cooling system, and therefore a cost savings.

In order to study the mechanisms to reduce wall and roof temperatures using cool paints, it is important to consider the mechanisms of heat transfer through wall and roof. Heat is transferred through a wall and roof by conduction, convection, and radiation. These heat exchanges can be reduced by an adequate selection of building materials and components. There is limited possibility to modify the convective component of heat because it is strongly dependent on the incidence of wind, which leaves the alternative strategy of reducing the conductive and radioactive components.

Insulation material primarily restricts conduction. Heat transference by radiation can be decreased by reducing the absorption of solar energy through the use of highly reflective materials on external surfaces, or by decreasing the amount of long-wave thermal energy radiated to the interior of the buildings through the use of low emissivity material applied to the internal surface of roofs. The emission qualities of the external painted surface help cool the wall and roof by irradiating absorbed energy reversely.

Non-metallic inorganic materials such as gypsum are greatly emissive and, when painted with highly reflective paints, they contribute to a reduction of external surface temperatures and restrict the flow of heat to the inside environment. Replacing the pigments of conventional paints with ''cool pigments'' modifies the absorption of infrared radiation. The conventional insulating paint allows only white color, which limits the beauty of variety color shades for precious architectural structures or buildings. Novel coating pigment offer new opportunity to balance between the beauty of coating and solar reflectance index.

Purpose of the study

1. To study different paint ingredient and paint system that result in paint with maximum solar reflective value.

2. To compare the physical thermal performance and cooling energy of simulated building which coated with three types of paint namely high solar reflective paint, conventional paint and uncoated.

3. To create mathematical model that prove the relationship between solar reflectance and thermal conductivity which cause heat gain reduction.

Significance of the study

Recent advances in paint chemical technology have allowed formulators to achieve a greater solar reflectivity versus traditional pigmentation technologies in functional coatings, while maintaining the appropriate light absorption in the visible spectrum to impart color. The ability of functional infrared reflective coating systems to lower heat build-up results in reduced heat gain, and lower energy costs related to cooling, and improved comfort and functionality of dark color exterior objects such as building façade, houses, roofing, park benches, hand railings, and even polymer concrete. This study will impart knowledge of infrared pigmentation technology to the reader, and explore potential new applications of infrared reflective pigmentation technology in composites.

Raising paint reflectivity can reduce cooling-energy use in buildings. High solar reflective paint also results in a lower ambient temperature that further decreases the need for air conditioning and retards smog formation.

Paints have four main constituents: binder, solvents, additives, and pigment, which are the major component. Pigment not only provides color, but also controls gloss, hiding power, strength, and permeability of the paint film. It also absorbs and reflects different parts of the sun's wavelength spectrum due to its chemistry and mineralogy. There are two basic classes of conventional pigments: organic, with a rather limited service life (lightfast) and opacity, and inorganic, which are generally more durable and less susceptible to the photochemical degradation caused by the ultraviolet light present in solar radiation. Inorganic pigments also have more stability under higher temperatures and are chemically inert to acids, alkali, etc.

In addition to the conventional inorganic pigments, there are several other special classes of non-conventional inorganic pigments (cool pigments) for producing energy-efficient colored paints. The most important technology in the production of cool paints is the formulation with inorganic colored pigments. This special group of nonconventional pigments presents spinel structure and is known for its highly visible opacity and high reflectance in NIR radiation. These pigments also present a long service life in normal environments, are heat stable and chemically inert. Paints colored with conventional pigments tend to absorb infrared radiation. However, when these pigments are replaced with cool pigments, the paint presents greater solar reflectance and thermal emissivity and thus absorbs less infrared radiation. This result yields much less consumption of electricity for air conditioners. Thus, we can reduce the energy consumption of 1 kWh, in the same way; we can reduce the CO_2 respectively.

Scope of the study

From an early study of a dissertation names energy saving in a small building by utilizing insulating microspheres ceramics pigment paint, this study intends to extend the knowledge of energy saving coating from only white microsphere ceramic as insulation paint to a more variety shades with high solar reflective paint. The study employs a range of different ingredient with grey colored coatings with various solar reflective properties, taking into account the effects of different painting systems. Using these coatings, a comparison of the energy use by electric cooling has been performed. In addition, other performance issues, such as mathematical model, will be further investigated.

The scope of this research is divided into three steps of works.

1. Optimizing the paint formula to achieve the highest solar reflective index

1.1 Different reflective index and heat gain test methods will be explored

1.2 Chemical ingredients such as cool pigment and painting system are varied to evaluate the solar reflective performance. The monitoring parameters comprise of thermal conductivity, emissivity, and thermal reflective index.

2. The performance testing condition of a small building coated with high solar reflective paint (Beger Cool UV Shield: pure acrylic paint, product of Beger Company, Thailand)

2.1 There are three buildings that will be tested. They are identical in size (4x4x2 m^3) and made from the same material, gypsum.

2.2 This work considers the heat transfer through gypsum only.

2.3 All buildings are furnished with an air conditioner, 22,000 BTU.

2.4 There are three conditions of testing.

2.4.1 The first case is that the building is not coated on each wall.

2.4.2 The second case is coated on each wall with conventional color paint.

2.4.3 The third case is coated on each wall with high solar reflective paint (Beger Cool UV Shield).

2.5 There are two color pigments (cool pigments) that are used to study, such as, white and white grey colors.

2.6 The period of testing is nine days and nine hours per day (8.00-17.00 local time). The data acquisition will be carried out in every hour.

2.7 Energy usage of the building means that the energy is consumed by the air conditioner.

2.8 The monitoring parameters comprise of the temperature of each wall, the energy consumption, ambient temperature and relative humidity and air velocity

2.9 The location for experimental is at BEGER company.

2.10 The concerned parameters about heat gain reduction of the simulated building are solar reflectivity, and thermal conductivity.

2.11 The physical thermal performance of simulated building is wall temperature, air velocity, ambient temperature, ambient relative humidity and energy consumption of air conditioner, OTTV, RTTV and total heat gain.

3. The mathematical simulation model of heat transfers through a small building coated with high solar reflective paint (Beger Cool UV Shield) varying solar reflectivity, thermal conductivity to achieve temperature difference.

3.1 A software simulation program such as Microsoft Excel (version 14.0), Mathcad, or MATLAB (version 5.0)

3.2 The various heat properties are used to analyze and they are varied by the color pigments that are painted on the simulation building.

3.3 The predicted results of various heat properties show the different energy consumption of air conditioner and the solar heat through building.

Benefit of the study

The study will derive mathematical model equation and will use the software simulation program to show the performance of high solar reflective paint of different "Color Shade" in reducing the temperature inside of the building and consequently cause energy saving. The result of energy saving will finally lead to an alternative way to Reduce Global Warming.

1. Building and construction in high solar intensity area can use high solar reflective paint to reduce heat accumulation inside the premise and hence the room temperature reduction. When most buildings absorb less heat, temperature in urban area get closer to suburban area then urban heat island effect can be decreased.

2. Using high solar reflective paint can not only reduces heat transfer through building, but also drastically reduces cooling energy consumed by air conditioning unit. If air conditioner consumes less electricity, there will be less carbon dioxide emission to the atmosphere and hence become another factor that helps reducing effect of global warming.