Air Conditioning in the Tropics: Cool Comfort or Cultural Conditioning?

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Since the combustion of fossil fuels is the leading causative factor in global climate change, the ''Western model'' of adopting energy-using technologies and using ever-greater amounts of energy will have important consequences for the future of human life on the planet if it is transferred on a wholesale basis to the developing world. It is thus important to try to understand, in the context of global development, the factors which drive the increased application of energy-using technologies, and whether there might be ways to satisfy human needs while limiting the environmental damage due to increased energy usage.

This paper explores the rapid growth in the use of air conditioners in two tropical countries; Ghana and Thailand. We first assess the energy impacts and capital requirements of this coming wave of technology adoption. The rapid growth in the use of air conditioners will represent a challenge for policy makers in both countries, who at a minimum must implement policies to improve their efficiency. However, we present evidence from Ghana and Thailand—based on empirical studies as well as personal experience—that air conditioners are often not necessary and may in many cases cause discomfort for tropical people who are not culturally conditioned to the technology. In addition, we discuss trends toward Western non-traditional dress, which reduces thermal comfort of people in the tropics and creates the need for mechanical cooling. We conclude with some suggestions for policies to promote alternative ways of keeping cool in the tropics, including building codes that encourage appropriate elements of traditional design, and dressing patterns that promote natural cooling.

INTRODUCTION

In a recent issue of an academic journal on building science, a European author wrote a witty and scathing attack on the particularly American obsession with air conditioning, exploring the technological and cultural origins of this obsession:

> ''Why do Americans so passionately wish to be cool in summer? What is the meaning of the grim resolve which so many show as they fire up their air conditioners in their cars and homes, to emit a withering, icy blast? Why must the lobbies of hotels and office blocks with pretensions be so much colder than those of hotels and office blocks without? Whence the truculence with which the right to be cold is maintained? All these qualities are immediately striking to the non-air-conditioned stranger; and to one who has lived in tropical Africa, without air-conditioning, something here cries out for explanation (Prins 1992: 251).''

Prins' diatribe evoked responses from several offended U.S. researchers. One of the responses was particularly defensive and lashed out at Prins' ''condescending language,'' ''pointless symbolizing,'' and ''relentless anthropologizing'' (Cowan 1992: 265). Apart from the real and perceived ''put down'' of Americans, the more important point of his article was to identify the social, cultural, and technological factors which led to the widespread use of air conditioning in the U.S. In southern Florida, for example, the percentage of homes with air conditioning increased from 5 percent to 95 percent in the 40-year period from 1950 to 1990.[1] One of the results has been a huge surge in power demand in the state.[2] What are we to make of this? Does this mean that occupants of 95% of Florida's households were uncomfortable in 1950? Or that advertisers and electric utilities have succeeded in the society-wide marketing of an electrical appliance that many Floridians do not really need?[3]

We disagree with the moralizing tone of Prins' comments, and we feel neither that there should be a sense of shame associated with the use of air conditioners nor a puritanical self-denial in one's decision to do without. These are personal judgments which depend on one individual and cultural comfort levels as well as on a variety of other personal preferences. At the same time, we feel that the wholesale adoption of mechanical air-conditioning as the primary cooling strategy throughout the developing world is fraught with environmental, social, and economic consequences, many of which can be avoided through a more culturally-sensitive approach to keeping cool.

In this paper, we argue that the need for cooling in tropical developing countries can be satisfied using a variety of strate-

gies—behavioral adaptations, climate-sensitive design, and low-energy cooling technologies—which recognize local cultural conditions. Further, we assert that such strategies will require neither sacrifice nor discomfort and will result in a significantly lower energy impact than would compressor-based cooling of buildings to a narrowly defined comfort range (23–26°C), derived from laboratory climate-chamber tests.

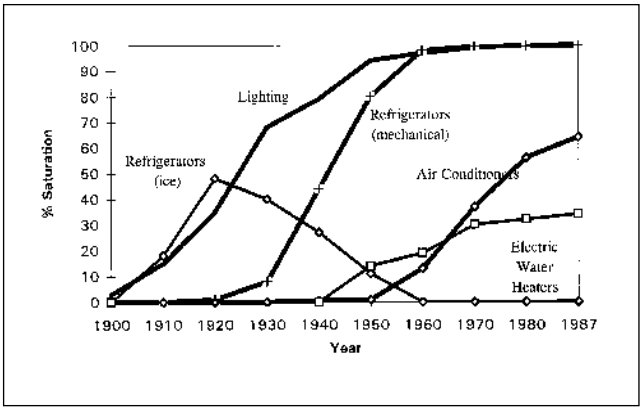
Drawing on our experience in two tropical developing countries—Ghana and Thailand—we discuss the implications of the mass marketing of air conditioners in the tropics. We begin with a brief history of the evolution of the appliance industry in the U.S., and the likely implications of the transfer of this model to developing countries. We then provide an overview of energy demand in Ghana and Thailand, along with projections of future demand due to residential air conditioning. Following this, we discuss traditional strategies for staying cool in the tropics as well as the physiology and cultural aspects of human comfort. We provide both empirical and anecdotal evidence that wholesale adoption of Western standards of human comfort may not only be wasteful of resources but may also be culturally inappropriate in the tropics. In conclusion, we argue that tropical people can often stay cool without air conditioning, or in most cases with significantly lower levels of air conditioning than assumed in the Western heating, ventilating and air-conditioning (HVAC) industry.

EVOLUTION OF THE U.S. APPLIANCE INDUSTRY

Figure 1 shows the rapid proliferation of household appliances in the U.S. during the first half of the 1900s.[4]

In the absence of an existing electric appliance industry, the electric generating companies had to create one (Clark 1977, Hughes 1983, Marcus and Segal 1989). The marketing of electric end-use devices occurred on several levels. Electric utilities marketed electric lighting and other appliances for the home in an effort to increase their profits by improving their ''load factor,'' a term referring to the extent to which customers use the installed capacity of the generating plant. By ''diversifying'' their load across the day, utilities could recoup more profits on the fixed costs of operating the plant (Hughes 1983: 220). In 1909, Commonwealth Edison opened an ''Electric Shop'' in downtown Chicago to show off and sell domestic appliances. In the same building, there was also an ''Industrial Power Room,'' to market motor-driven machines to factory owners and managers (Hughes 1983: 223).

Figure 1. *Increase in Saturation of U.S. Electrical Appliances*



By 1940, the electric light had almost completely replaced the gas light in U.S. homes, and mechanical refrigerators had replaced ''ice'' boxes as the dominant mode of cooling food. The period after World War II, when incomes rose rapidly, saw the largest increases in household mechanization, and by 1960 nearly all U.S. houses had both electric lighting and refrigeration.

Air conditioning was much slower to take root. Prior to 1940, there was virtually no air conditioning in U.S. homes. In the 1940 *Statistical Abstract of the U.S.*, air conditioners were not even listed as a household appliance. By 1950, the *Abstract* listed room air conditioners, not as a household item, but rather as a manufactured good (i.e. the number and value of units sold during the 1940s). Figure 2 shows the rapid increase in sales of room air conditioners from 1940 to 1969—an increase in annual sales of more than 500-fold! By 1987, nearly two-thirds of U.S. homes—67.6 million—had an air conditioner (*Statistical Abstract of the U.S.* 1990). And by 1989, the proportion of new single-family homes equipped with air conditioning had reached 77 percent. (Kempton and Lutzenhiser 1992)

OVERVIEW OF ENERGY DEMAND IN THAILAND AND GHANA

Figure 3 compares per-capita residential electricity use in three countries—Ghana, Thailand and the U.S. Residential

Figure 2. *Increase in Sales of U.S. Air Conditioners*

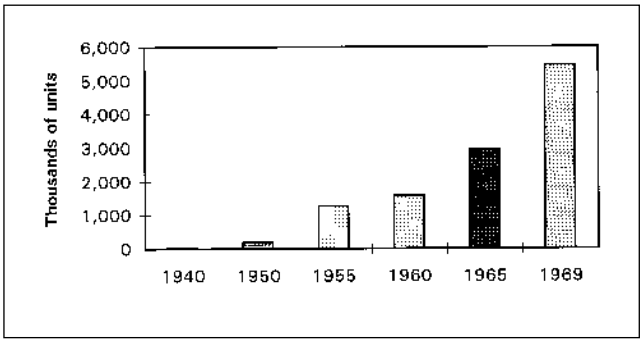
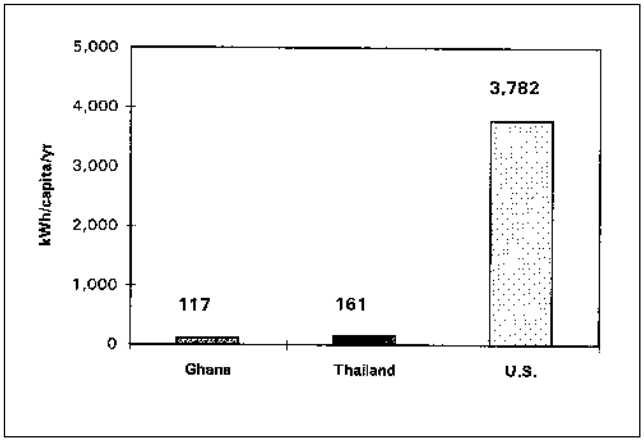


Figure 3. *Residential Electricity Usxe in the U.S., Thailand, and Ghana, 1991*



demand in Ghana is driven primarily by electric lighting and refrigeration. In Ghana, a country with a per-capita income of just US$452 per year,[5] only 60% of homes are electrified (Mintah 1995). It is still somewhat of a luxury to have a refrigerator, and very few homes have air conditioners. Largely due to its higher average income levels—US$1,774 in 1991—Thailand has seen a much more rapid proliferation of household appliances. In Bangkok, the capital and largest city, 40% of houses have air conditioners, and more than 90% have refrigerators. Outside of Bangkok, appliance saturations are much lower—just 4% for air-conditioners and 50% for refrigerators. (TLFS 1993) But Thai energy planners expect saturations for both of these appliances to reach nearly 100% within the next 40–50 years. (Chongpeerapien 1994)

Ghana

Ghana, located in West Africa, occupies an area of approximately 92,100 square miles and has a total population of about 15 million. Like most African countries, about 20% of Ghana's population live in urban areas. As of 1992, 33% of the total population had access to electric power (Brew-Hammond 1994). However, the government's commitment to extend electric power to all corners of the country increased this figure to 60%. The main source of electric power in the country is the Volta Hydroelectric Dam. Drought conditions in most of the dam's catchment areas since the early 1980s have resulted in reduced electric power generation, and rationing has become a routine response to the frequent brown-outs and black-outs.

In 1983, the government initiated an Economic Recovery Program (ERP). The ERP resulted in average GDP growth of 5.9% between 1984 and 1987, and 4.2% between 1988 and 1991. Accompanying this growth was a rapid increase in electric energy consumption—from 1,810 GWh in 1984 to 5,732 GWh in 1990 (Brew-Hammond 1994). Since 1986, the electric power market has been growing at an average rate of 10% annually. However, this growth rate is expected to slow down to between 6% and 7% through the year 2000 (Power Sector Reform Committee 1994). This will further worsen the capacity deficit problem. System peak demand for 1996 is projected at 1,057 MW, while the projected firm capacity is just 958 MW[6] (VRA 1993). Even though a 300 MW thermal plant is being constructed as a short-term solution to the electric power supply problem (Berko 1994), there will not be any reliable reserve margin until steps are taken to address the problem on a long-term basis.

Currently, Ghana's air-conditioning load is a very small percentage of total end-use demand. Electric power is mostly used for lighting, radios, televisions, refrigeration and a few industrial purposes. In rural areas, the only air-conditioning load is usually in towns with either a big factory or an industrial processing center. On the other hand, urban areas have a relatively much larger air-conditioning load, and many new homes in urban areas have air conditioners.

Although air conditioners are imported and expensive, they have rapidly becoming a major part of the domestic appliance market. Table 1 shows the rapid growth in imports of window air conditioners into the country. Despite a temporary drop in numbers from 1991 to 1992, there was a dramatic increase in total numbers of units imported from 1993 to 1994.

In Ghana, the hottest part of the year is the dry season, which lasts for up to seven months. Temperatures during this period vary by only 5° to 7°C. If we make a conservative assumption that the average air-conditioner unit is used six hours per day during the dry season, then a minimum of 175 GWh of energy per year (about 3% of total electrical

Table 1. *Window Air-Conditioner Units Imported into Ghana between 1991 and 1994*

Year	# of Units	% Change
1991	76	– 88
1992	9	
1993	6,691	74,244
1994	13,423	101

Source: Statistical Services of Ghana, 1995.

energy consumption) was needed to run only the window air-conditioners that were imported into the country officially in 1994.[7] If the current rate of increase in imports continues, the electric power demand due to air conditioners will rise dramatically in the near future. Already, the utilities lack adequate investment capital of their own for power plant expansion. Considering the increasing electric energy supply problems facing the country, urgent measures are required to help keep the air-conditioning load in check.

Thailand

Thailand, with a population of 55 million, is located in the center of the booming Southeast Asia region. Nearly all of the country is electrified, and more than 80% of dwellings throughout the country have electrical service. (TLFS 1993) Largely due to the promotion of manufacturing exports, the Thai economy has experienced rapid economic growth during the past decade—GDP grew at an average annual rate of nearly 10% during the period from 1985 to 1995. This economic growth has been accompanied by equally rapid increases in primary energy demand. About a third of primary energy is provided in the form of electricity for homes, buildings, and factories. Peak electricity demand grew by 12.0 percent between 1985 and 1995—from 3,800 MW to 12,300 MW. The increase in electricity demand is expected to slow to 8.6 percent between 1996 and 2000 and then to a slightly lower rate, 6.1 percent, between 2001 and 2006, when peak demand is expected to reach 34,500 MW (TLFS 1995).

While the rate of growth in electricity demand is slowing, the average rate is still two to three times as high as in industrialized countries, and Thailand is faced with the need to bring more than 1,000 MW of capacity on line annually over the next decade. To meet this challenge, the state-owned generating company, the Electricity Generating Authority of Thailand (EGAT), has a plan to invest a total of $36 billion in power plant construction during the period 1991 to 2006. In 1993, EGAT also established a Demand-Side Management (DSM) Office and began to implement a five-year pilot DSM plan which they hope will reduce demand by 1,400 peak MW by the end of 1998. Testing and labeling of residential air conditioners, in an effort to increase the efficiency of the air-conditioner stock, will be a centerpiece of the Thai DSM effort.[8]

During the early 1990s, air-conditioner sales in Thailand increased at an average rate of more than 15 percent, and total production increased at an even greater rate, as exports of air-conditioners tripled over a five year period (du Pont, Ka-yuraphan, and Birner 1995). According to the Thai electricity load forecast, the stock of residential air conditioners is expected to increase nearly five-fold between 1991 and 2006, to reach 4.8 million units. And although refrigerators are currently the largest residential load, they will be surpassed by air conditioners before the end of the century:

> The highest electricity consuming appliance in Thailand in 1991 was the refrigerator, followed by air conditioners, rice cookers and lighting. However, consumption of electricity from air conditioners will surpass that of refrigerators by the end of the Seventh Plan [1997]. By the end of the Ninth Plan [2007], consumption of electricity for air conditioning will be nearly twice as high as that of refrigerators. (TLFS 1993: 2–19)

Indeed, compared to refrigerators, air conditioners will account for three times as much new electricity demand in the Thai residential sector over the next decade—38 percent of new residential demand for air conditioners versus just 11 percent for refrigerators.[9] The cost of adding new capacity to power these air conditioners could exceed US$ 2 billion, and it will cost consumers nearly US$ 700 million in annual energy bills to operate the air conditioners.[10]

TRADITIONAL WAYS OF STAYING COOL

Even though the temperature variation within the year is not large in the tropics, traditional lifestyles have evolved around the prevailing climatic conditions. Activities are planned based on diurnal temperature variations. Farmers and laborers do most of the strenuous work that involves a lot of muscle activity during the early morning or late afternoon. For example, in the rural areas of most sub-Saharan African countries and Thailand, there is a large population of peasant farmers. Many of these farmers have to walk several miles to their farms each day. To avoid having to walk these distances in the hot sun, they set out to their farms early in the morning (between 4am and 5am) before the sun is out. They work very hard in the morning and stop to rest before the afternoon heat sets in.

Clothing

Clothing habits have also been influenced by the climatic conditions. Cotton is the prevalent clothing material, since it can keep the body cool in very warm conditions. Light and bright colors are most often used, since they reflect rather than absorb heat. Clothes are designed in a way that allows ample aeration. Western dressing styles are often modified to suit the climate. In Ghana, for example, the Western suit has been modified with short sleeves and it is called a "political suit.'' In Thailand, a similar, short-sleeved suit (*prarachatan)* is commonly worn by government officials and by many workers in the private sector. Increasingly, though, office workers in both countries have taken to wear-

ing long-sleeve white shirts with ties. Government ministers and their entourage wear full Western suits as a rule.

Housing Design

Traditional tropical architecture includes a number of features designed to keep occupants cool. In Thailand, traditional houses are built to promote natural ventilation, with high, vented roofs and large windows to add wind flow. Houses were also commonly built on stilts along the edge of waterways such as rivers and canals. Unfortunately, modern, concrete Thai housing retains none of these features: little attention is paid to house orientation and wind flows, windows are much smaller, ceilings are lower, and plants and trees are typically cleared from the site during construction. In addition, the typical new house has neither wall nor ceiling insulation.

Traditional Ghanaian houses are built with windows that allow passive ventilation. Wood is most often used for windows, and rooms are always designed to allow cross ventilation. The main building material is Portland cement. Due to its dense nature, it takes a long time to absorb most of the heat during the day. This property helps keep the rooms cool when it is relatively hot outside during the day. During the night, it slowly releases its absorbed heat and keeps the room warmer than it is outside. In this way, the indoor temperature does not vary greatly throughout the day. The architectural design of traditional Ghanaian houses also includes large porches or balconies that allow free flow of fresh air in and out of the buildings.

It is actually possible to measure and compare the relative comfort of houses. Chancellor (1994) has used an indicator called the Index of thermal stress (ITS) to represent relative human comfort in the houses.[11] He has used this indicator to quantify ''comfort'' levels in a number of different traditional and modern-style Thai houses. A measure such as ITS could potentially be used as an indicator of how well houses are designed for natural cooling.

Even when ''modern style'' houses are built without regard for natural ventilation, the need for mechanical cooling can be greatly reduced by requiring modest levels of insulation. The impact of adding just ceiling insulation can be dramatic, and this option is being considered in Thailand's residential demand-side management program. In a carefully monitored study of a wooden-frame Thai house, indoor and outdoor temperatures, ceiling temperature, and air conditioner and whole house energy use were monitored over a period of several months. After the first month, insulation was installed under the roof above the upstairs bedroom (where the sole air conditioner was located), and a smaller, more efficient air conditioner was installed. The study found that the insulation alone significantly reduced the ceiling temperature, making the bedroom more comfortable. In addition, there were significant savings from the combination of insulation and a downsized more efficient air conditioner (Parker 1995).

Landscaping provides shade and comfort during hot periods. Tropical trees are usually short with broad leaves and a lot of branches. In certain areas, the trees are planted around the houses preventing the sun from directly hitting the house. The shade provided by the trees can significantly reduce the air-conditioning load and also serve as comfort zones during periods of intense heat.

TROPICAL ADAPTATION TO HEAT

There is no one standard of human comfort. In fact, there is much individual variability in this respect. This is due to the human body's ability to adapt to prolonged exposure to certain environmental conditions. Variation in comfort level may be inherited or acquired through ailments, physical training, diet, clothing habits, living habits, etc. It also varies with sex, race, age and other physiological conditions. On the average, tropical peoples are comfortable at higher ambient temperatures than are people from northern climates.

An empirically derived comfort range

A recent study by Busch (1990) provides an interesting example of how Western-derived comfort norms do not apply in the tropics. Busch surveyed more than 1,100 people in naturally ventilated and air-conditioned office buildings in Bangkok to assess their level of thermal comfort. The ASHRAE[12] comfort zone is defined as an effective ambient temperature in the range of 23° to 26°C. Using the same criteria for thermal acceptability as in the ASHRAE guidelines, Busch found a broader effective temperature range than in previous studies—from 22° to 30.5°C. Additionally, he found a significant distinction between comfort levels of groups of workers in the naturally ventilated and the compressor-cooled buildings. Workers in naturally ventilated buildings were typically comfortable at temperatures 3°C higher (up to 31°C) than were workers in compressor-cooled buildings (up to 28°C).

The implications of Busch's work are extremely significant in the context of Thailand, where the design temperature for cooling in the Thai building industry is 25°C, and most Thai office buildings and hotels are cooled to a level several degrees below this temperature. The acceptable comfort level should be from 28° to 31°C, depending on whether the worker is accustomed to naturally ventilated spaces (Busch 1992). In light of the fact that a 1°C decrease in indoor temperature can save from 3–10% of air-conditioning energy use, this a very significant finding.[13] Lovins (1992) conserva-

tively estimates 2–4 percent per degree C and Busch (1990) estimates as much as 10 percent per degree C.

THE SOCIALIZATION OF AIR-CONDITIONING

In order to understand the interplay between comfort and cooling, it is important to recognize that social factors play a large role in determining what is ''comfortable.''[14] In tropical developing countries, there is a growing mass identification with Western lifestyles. Many ''justifications'' given by air-conditioner users are common expressions of a global process of Westernization and technology adoption which is being superimposed over indigenous cultures. The use of air conditioners is now so entrenched in Western societies that when one feels a little warm, the first (and often the only) means of cooling that one considers is the air conditioner. The technology has blinded many to the different traditional means of cooling, such as fans (both manual and mechanical), use of light-weight and light-colored clothing, and reduced body activity. This observation is more easily made clear if one grew up in an environment where air-conditioners are not prevalent. People tend to think that you are strange if you decide not to switch on the air-conditioner on a hot day.

Many tropical natives adopt this addiction to the air conditioner when they stay in the West for long periods of time. For example, Ghanaians and Thais are increasingly traveling and living outside their country, especially in temperate regions. These travelers return home periodically for holidays and during special occasions. When they do, most of them use air conditioners during the hot periods, since their stay in temperate countries has socialized them to use the air conditioner on hot sunny days. Some people adopt Western customs and technologies (such as air conditioners) as a symbol of an improvement in lifestyle. Just as the adoption of Western architectural styles requires a greater reliance on compressor-based cooling, the adoption of Western styles of dressing requires a lower ambient temperature in order to remain comfortable.

Lessons from Akosombo, Ghana

An example from Ghana illustrates the fact that mechanical cooling is often uncomfortable for many tropical people and that ''getting used to it'' may require a process of socialization. Akosombo is a small town located among the hills beside the electricity generating facilities on the Volta Hydro electric Dam. The town is divided into two sections. One section, which is on top of a hill, is inhabited by senior officers of the Volta River Authority. The other section is for the junior officers. All the houses in the senior officers' section and a few of the houses in the junior officers' section of town have window air conditioners. Even though the officers pay a very low flat price (independent of how much is used) for electricity consumption in both sections, very few of the officers use their air conditioners. A couple of senior officers' indicated that they are not comfortable with mechanical air-conditioning. They claim that it makes them feel like they are living in a refrigerator and sometimes causes them to break into chills. This discomfort may be due to the fact that they were not socialized to use air conditioners as a means of cooling when they were growing up. Most people in Akosombo use either mechanical or manual fans to keep themselves cool if the need arises.

Air conditioner as a status symbol

In Ghana, the air conditioner's role as a status symbol is often at least equal to its role as a cooling device. Having an air-conditioner in the home confers the image of a modernized, Western-type of family. Air conditioners are also becoming *de rigeur* in the business community. In the past, air-conditioners were mostly limited to the offices of multinational companies (that employ a lot of expatriates), foreign embassies, and residential areas mostly inhabited by expatriates from the West. Today, most new offices are equipped with air conditioners, and many existing offices have been retrofitted with window air conditioners to give the impression that the company is efficient, modern, and progressive.

At Thai schools and universities, having an air conditioner is a function of seniority and status. All of the Thai government primary and secondary schools are naturally ventilated. At teaching colleges, there are no air conditioners in the classrooms, but the meeting rooms and faculty offices are mechanically cooled. At the most prestigious Thai university, the undergraduate classrooms are naturally ventilated, while the graduate classrooms are air-conditioned.

For Thai families, the decision to purchase an air conditioner is often a function of income. Above a certain income level, people generally decide to automatically buy air-conditioners. One Thai man installed an air conditioner in a bedroom of his house on the outskirts of Bangkok fifteen years ago, after several neighbors had done so. After using the air conditioner for a year, he decided that he was more comfortable without it and set it aside in a back room, where it sits gathering dust and rust today. This is not an isolated anecdote. A similar incident occurred recently when an American man married a Thai woman from a rural village. When the groom's parents came to Thailand, the parents of the bride, who were respected elders in the village, bought and installed an air conditioner just to keep the U.S. ''guests of honor'' cool while they stayed in the village during the wedding party. Although they had no use for the air conditioner themselves, they felt it would be a dishonor for them if the

U.S. couple were not comfortable in their house. Since the wedding, the Thai family has not used the air-conditioner.

CONCLUSIONS

Physiological and cultural adaptations have traditionally allowed tropical peoples to keep cool without air conditioning. In Thailand, for example, empirical studies have shown that most people are comfortable up to temperatures of 28°C, and people who work in non-air-conditioned buildings are comfortable at a temperature of 31°C. Yet, the ''design temperature'' of Thai commercial buildings in 25°C, and offices are typically cooled to several degrees below this temperature. This makes occupants uncomfortable and also wastes significant amounts of energy. At the same time, observation of populations that have not been ''socialized'' to use mechanical air conditioners indicate that they may not be comfortable with the new technology. In the Ghanaian town of Akosombo, families provided with air conditioners and heavily subsidized electricity choose not to use them because the air conditioners make them feel like they are ''living in a refrigerator.''

Despite this evidence that tropical peoples have adapted to higher ambient temperatures and are often not comfortable with mechanical air-conditioning, the adoption of air conditioners will likely proceed unabated in tropical developing countries. In rural Thailand, only four percent of homes have air conditioners, and this is expected to reach 100% within the next 40 years. Air conditioners are expected to account for nearly 40% of new electrical demand in Thailand's residential sector by the year 2000. A similar, though slower, trend of uptake of air conditioners is expected in Ghana.

We believe that developing-country governments can act on two fronts to reduce the energy and environmental impacts of the coming wave of air conditioners. First, they can design and implement policies that will reduce the need to install air conditioners. Building codes can encourage traditional forms of architecture with increased overhangs, high ceilings, natural cross ventilation, proper building orientation and landscaping to reduce solar gain. The trend toward wearing the Western suit and tie also reduces human comfort and results in the need to keep office buildings several degrees cooler than if office workers were to wear traditional, lightweight, light-colored suits with short-sleeves and open necks. Urban centers are also afflicted with the ''heat island'' effect, which results from the reduction of vegetative cover and the increase of dark-colored city surfaces made of asphalt, concrete, and roofing materials. Since 1970, the average temperature in Bangkok has increased by 2.0°F, resulting in millions of dollars in extra cooling cost annually (Sullivan 1996). The heat island effect can be reduced by promoting the use of light-colored, heat-reflecting building and construction materials as well as the retention and expansion of trees and other landscaping in urban areas.

A second area where policy makers can take action is by ensuring that the coming wave of air conditioners operate as efficiently as possible. Thailand's Demand-Side Management (DSM) Office is encouraging testing and labeling of air conditioners and will provide financial incentives for the purchase of high-efficiency units. The DSM Office is also considering ways to increase the installation of ceiling insulation in new homes in order to reduce heat gain and to allow for the installation of smaller air conditioners. Such policies are an essential part of a national strategy for cooling. An additional policy action, which was recently taken by the Department of Energy in the Phillippines, is the adoption of minimum energy-efficiency standards for air conditioners. The establishment of efficiency standards will help to force inefficient units off the market and will significantly reduce consumers' energy bills.

ACKNOWLEDGMENT

We would like to thank Dr. Willett Kempton for his inspiring comments and feedback which helped to shape and greatly improve the ideas presented in this paper.

ENDNOTES

1. The trend toward increased use of air conditioning is most prevalent in Florida homes, but is a nationwide phenomenon as well. The proportion of new, single-family homes equipped with air conditioning increased from 33 % in 1970 to 77% in 1989 (Kempton and Lutzenhiser 1992).

2. In the 15 years from 1957 to 1972, installed electrical capacity in Florida rose six-fold, while the population increased less than 100 percent (Rodgers 1972).

3. One major factor that has led to widespread adoption of air-conditioning in Florida was the move away from naturally ventilated housing. Ironically, even as this trend was occurring across the southern U.S. in the early 1950s, the U.S. Department of Housing and Urban Development was developing guidebooks for the construction of naturally ventilated homes in hot and humid developing countries, for distribution overseas by the U.S. Agency Lovins for International Development (U.S. HUD 1953).

4. A fifth appliance, heating systems, is not included, due to the difficulty in comparing the many different types of heating systems, such as wood, coal, gas, oil, electric. Except for water heaters, which are split roughly

evenly between gas and electricity, the four appliances in this table are electrical.

5. Per capita income figures for Ghana, Thailand and the U.S. are from the World Resources Institute. (WRI 1994: 256)

6. These projections were made with the assumption that the first 200 MW thermal plant will be commissioned in early 1996. Unfortunately, financial constrains has delayed the project and the first 200MW has as to date not been commissioned.

7. The actual import figure may be much higher due to smuggling and improper record keeping.

8. One unintended by-product of the air conditioner labeling program, which began in early 1996, was that the marketing efforts appear to have accelerated the rate of increase in air conditioner sales (Lemoine 1996).

9. Calculated from Thai load forecast data (TLFS 1993: 220).

10. Capacity costs assume US$ 1,400 per kW based on data on EGAT 1992. Air conditioner energy bills are based on assumptions about operating time and future efficiencies in the Thai electricity load forecast (TLFS, 1993), and assume an electricity price of 8 cents/kWh.

11. ITS is an approximation of the amount of perspiration that will be caused to occur per unit time for a given individual human being. ITS units are expressed in grams of sweat per hour.

12. Association of Heating, Refrigerating, and Air-Conditioning Engineers.

13. Lovins (1992) conservatively estimates 2–4 percent per degree C and Busch (1990) estimates as much as 10 percent per degree C.

14. Lovins (1992) described the forces driving demand for air-conditioning as a combination of physiological, technological, and socio-economic factors. He defines three distinct, and sometime overlapping, paradigms of human comfort; social science, engineering, and economic.

REFERENCES

Berko, Kofi Jr. 1994. ''Potential Issues and Problems in Using DSM Programs to Address the Electric Power Demand Crisis in Ghana (West Africa),'' *In Proceedings of the ACEEE 1994 Summer Study on Energy Efficiency in Buildings, 6:11–17.* Washington D.C. and Berkeley, Calif.: American Council for an Energy-Efficient Economy,

Brew-Hammond, Abeeku, 1984. ''Finance and Markets for Electric Power Development in Ghana'' in *Science in Africa: Energy for Development Beyond 2000.* 71–121. Washington, D.C.: American Association for the Advancement of Science.

Busch 1990. ''From Comfort to Kilowatts: An Integrated Assessment of Electricity Conservation in Thailand's Commercial Sector.'' Ph.D. Thesis, Energy and Resources Group, University of California Berkeley. And Report No. LBL-29478. Lawrence Berkeley Laboratory. August.

Busch, J. 1992. ''A Tale of Two Populations: Thermal Comfort in Air-Conditioned and Naturally Ventilated Office in Thailand.'' *Energy and Buildings* 18(3–4): 235–250.

Chancellor, W.J. 1994. ''Cool Tropical Buildings: Lessons from Old-Style Designs.'' *Building and Environment*. 29(1): 5–12.

Chongpeerapien, T. 1994. Thai Load Forecast Subcommittee. Personal communication.

Clark, R. 1977. *Edison: The Man Who Made the Future*. New York: G.P. Putnam's Sons.

Cowan, R.S. 1985. ''The Industrial Revolution in the Home.'' In *Technology*. Milton Keynes, U.K. Open University Press.

Cowan, R.S. 1992. ''Condis, Coolth, and Culpability.'' *Energy and Buildings* 18(3–4): 265–266.

EGAT (Electricity Generating Authority of Thailand). 1992. Power Development Plan: 1991–2006 (Update). System Planning Department.

du Pont, Ka-yuraphan, S. And S. Birner. 1995. ''Thailand's Energy-Efficiency Market: Potential for Investment.'' Bangkok, Thailand: International Institute for Energy Conservation.

Feustel, H. Almeida, A. de, and C. Blumstein. 1992. ''Alternatives to Compressor Cooling in Residences.'' *Energy and Buildings* 18(3–4): 269–286.

Fujii, H. and L.Luzenhiser. 1992. ''Japanese Residential Air Conditioning: Natural Cooling and Intelligent Systems.'' *Energy and Buildings* 18(3–4): 221–234.

Goldemberg, J., Johansson, T.B., Reddy, A.K.N., and R.H.Williams. 1988. *Energy for a Sustainable World.* New Delhi: Wiley Eastern Limited.

Hamilton, D. 1962. *Consumer Economy*. Boston: Houghton Mifflin.

Horowitz, D. 1985. *The Morality of Spending: Attitudes Toward the Consumer Society in America, 1875–1940.* Baltimore: The Johns Hopkins University Press.

Hughes, T.P. 1983. *Networks of Power: Electrification in Western Society, 1880–1930.* Baltimore: The Johns Hopkins University Press.

Kempton, W. and L. Lutzenheiser. 1992A. *Energy and Buildings* 18(3–4) A Special Issue Devoted to Air Conditioning: The Interplay of Technology, Comfort, and Behavior.

Kempton, W., Feuermann, D. and A.E. McGarity. 1992B. ''I Always Turn It On 'Super': User Decisions About When and How to Operate Room Air Conditioners.'' *Energy and Buildings* 18(3–4): 177–192.

Kempton, W. 1994. Center for Energy and Environmental Policy. University of Delaware. Personal communication. October.

Kyrk, H. 1922. *A Theory of Consumption*. Boston: Houghton Mifflin.

Lebergott, S. 1993. *Pursuing Happiness: American Consumers in the Twentieth Century.* Princeton: Princeton University Press.

Lee, M.J. 1993. *Consumer Culture Reborn: The Cultural Politics of Consumption.* New York: Routledge.

Lovins, A. 1992. ''Air Conditioning Comfort: Behavioral and Cultural Issues.'' Implementation Paper # 4. Boulder: Competitek. August.

Lemoine, Y. 1996. Ontario Hydro Co. Advisor to Demand-Side Management Office, Electricity Generating Authority of Thailand. Bangkok, Thailand. Personal Communication. May.

Marcus, A.I. and H.P. Segal. 1989. *Technology in America: A Brief History.* New York: Harcourt Brace Jovanovich.

Mintah, 1995. Ministry of Mines and Energy. Ghana. Personal Interview. January.

Parker D. and S. Ka-Uraphan. *Energy and Buildings*. NEED REFERENCE.

Power Sector Reform Committee, 1994. Strategy and Action Plan for Implementing Government Policy Objectives. Accra, Ghana : Ministry of Energy and Mines. October

Prins 1992. ''On Condis and Coolth.'' *Energy and Buildings* 18(3–4): 251–258.

Rodgers, W. 1972. *Brown Out: The Power Crisis in America.* New York: Stein and Day.

Rosenberg, N. 1972. *Technology and American Economic Growth.* Armonk, N.Y.: M.E. Sharpe.

Statistical Abstracts of the U.S., 1940, 1950, 1960, 1970, 1980, 1990.

Statistical Services of Ghana, 1995.

Sullivan, R. 1996. ''Proposal for the Study of the Urban Heat Island in Bangkok, Thailand.'' Berkeley, Calif.: Lawrence Berkeley Laboratory.

TLFS (Thai Load Forecast Subcommittee). 1993. ''Load Forecast for the Thailand Electrical System.'' Volume 2. Bangkok, Thailand. June.

TLFS (Thai Load Forecast Subcommittee). 1993. ''Update to Load Forecast for the Thailand Electrical System.'' Bangkok, Thailand. October.

U.S. HUD. 1953. ''Physiological Objectives in Hot Weather Housing: An Introduction to Hot Weather Housing Design for the Use of United States A.I.D. Missions.'' Washington, D.C.: Department of Housing and Urban Development, Office of International Affairs.

Veblen. T. 1899. Theory of the Leisure Class. New York: Macmillan.

VRA, 1993. Volta River Authority Corporate Plan 1994–8.

WRI (World Resources Intstitute). 1994. *World Resources 1994–95: A Guide to the Global Environment.* New York: Oxford University Press.