REPORT ON THE 1989 THAILAND WORKSHOP ON END-USE-ORIENTED ENERGY ANALYSIS

edited by

Eric D. Larson
Center for Energy and Environmental Studies
Princeton University, Princeton, New Jersey, USA

April 1990

MAIN OFFICE

420 C Street, N.E.
Washington, D.C. 20002
Telephone: (202) 546-3388
Telefax: (202) 546-6978

ASIA OFFICE

10/4 Soi 49/7 Sukhumvit
Bangkok 10110 Thailand
Telephone (662) 392-3936
Telefax: (662) 225-6462

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Eric D. Larson
Center for Energy and Environmental Studies
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with contributions from

Evan Mills
Lars Nilsson
Department of Environmental and Energy Systems Studies
Lund University, Lund, Sweden

Deborah Bleviss
Mark Cherniack
International Insitute for Energy Conservation
Washington, DC, USA and Bangkok, Thailand

Steven Nadel
American Council for an Energy Efficient Economy
Washington, DC, USA

John Busch
Lawrence Berkeley Laboratory
University of California, Berkeley, California, USA

The International Institute for Energy Conservation (IIEC) is a not-for-profit organization founded in 1984 to expedite the implementation of energy efficiency throughout the developing world.

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REPORT ON THE 1989 THAILAND WORKSHOP ON END-USE-ORIENTED ENERGY ANALYSIS

EXECUTIVE SUMMARY

The 1989 Thailand Workshop on End-Use-Oriented Energy Analysis was held in Bangkok from October 24 to November 3, 1989 as part of the International Institute for Energy Conservation's long-term commitment to fostering the implementation of energy efficiency in Thailand. The primary objective of the workshop was to inform and train Thai analysts, planners and policy-makers in the government, electric utilities and universities in energy end-use analysis and least-cost planning techniques. A secondary goal was to use the Thai workshop as a model for training seminars that would be undertaken in other countries in the future.

The idea for a Thai workshop emerged from the 1988 conference, "Energy Efficiency Strategies for Thailand: the Needs and the Benefits," organized by the Thai Ministry of Science, Technology and Energy, the Federation of Thai Industry, King Mongkut's Institute of Technology, Chulalongkorn University, the Asia Pacific Regional Office of the United Nations Environment Program, and the International Institute for Energy Conservation. Based on discussions at that conference, its organizers concluded that such training seminars would facilitate the development of in-country capabilities to undertake the analytical studies needed to identify cost-effective energy conservation opportunities, to integrate energy efficiency with energy supply in "least-cost" planning, and to develop policies and programs for implementing energy efficiency.

These analytical skills are needed to help deal with the electricity crisis facing Thailand. The growth in demand for electricity has been nearly twice as large as that forecast by government planners in the last national plan. Electricity demand has nearly tripled in the last decade. The generating reserve margin has reached a dangerously-low 3-5%. Government forecasts show demand growth averaging about 10% per year to 2001, corresponding to a GDP-elasticity of demand of 1.5. The state-owned Electricity Generating Authority of Thailand (EGAT) will not be able to finance all of the new generating capacity that would be needed to meet this forecast demand.

By emphasizing end-use efficiency improvement, economic growth can be maintained without the need for massive energy supply expansions associated with such forecasts of energy demand. The energy efficiency route would typically be less costly and less environmentally harmful. An exercise carried out at the End-Use Analysis Workshop to explore alternative future electricity scenarios for Thailand indicated that a GDP-elasticity of demand of about 0.7 could be achieved through increased emphasis on energy efficiency improvement. For these alternative scenarios, the electricity demand in 2001 would be about half of the official government forecasts (Fig. S.1). The analysis behind the workshop scenarios is preliminary, but the results suggest that there are significant end-use efficiency improvements that could be made cost-effectively to reduce the need for new generating capacity in Thailand. Scenario analyses such as that shown in Fig. S.1 could be used as the basis for developing policies and programs to achieve electricity savings in practice in Thailand.

The Workshop was co-organized by the Energy Research and Training Center of Chulalongkorn University (Bangkok), the Center for Energy and Environmental Studies of Princeton University (USA), and the International Institute for Energy Conservation (Washington, DC and Bangkok). It was held at Chulalongkorn University. The International Institute for Energy Conservation provided primary funding for the workshop. Additional support came from the US Agency for International Development (Washington, D.C.), the Swedish Institute (Stockholm), and the Department of Environmental and Energy Systems Studies, Lund University (Lund, Sweden).

Approximately half of the Thai participants were from the government and electric utilities and half were from Thai universities. Participants included analysts and planners from the National Energy Policy Office (NEPO), the National Energy

Administration (NEA), the Electricity Generating Authority of Thailand (EGAT), the Provincial Electricity Authority (PEA), the Energy Conservation Center of Thailand (ECCT), the Thailand Development Research Institute (TDRI), the Siam Cement Company, and professors from Chiangmai, Chulalongkorn, Kasetsart, Khon Kaen, and Prince of Songkla Universities and King Mongkut's Institute of Technology at Bangkok and Thonburi.

Instructors from the Indian Institute of Science (Bangalore), the University of Sao Paulo (Brazil), Lund University (Sweden), Lawrence Berkeley Laboratory, Princeton University and the American Council for an Energy-Efficient Economy (USA) lectured on methodologies of end-use energy and economic analysis, electricity use in industry and buildings, new energy efficient technologies, rural electrification, alternative scenarios of electricity demand for India and Brazil, and implementation of electricity conservation. Following the daily morning lectures, the afternoons were spent working through end-use analysis exercises using spreadsheet software on personal computers. The complete set of exercises are available in a companion document to this report.* On the final full day of the workshop the participants made short presentations of some of their analytical work.

There was a strong concensus among both participants and instructors that the workshop was highly successful. This was reflected in part by lively discussions, by the extra hours participants spent working before and after the scheduled sessions, by the high quality of their final presentations, by the enthusiasm generated for undertaking follow-on activities, and by written responses to an evaluation form.

THAILAND END-USE ELECTRICITY DEMAND

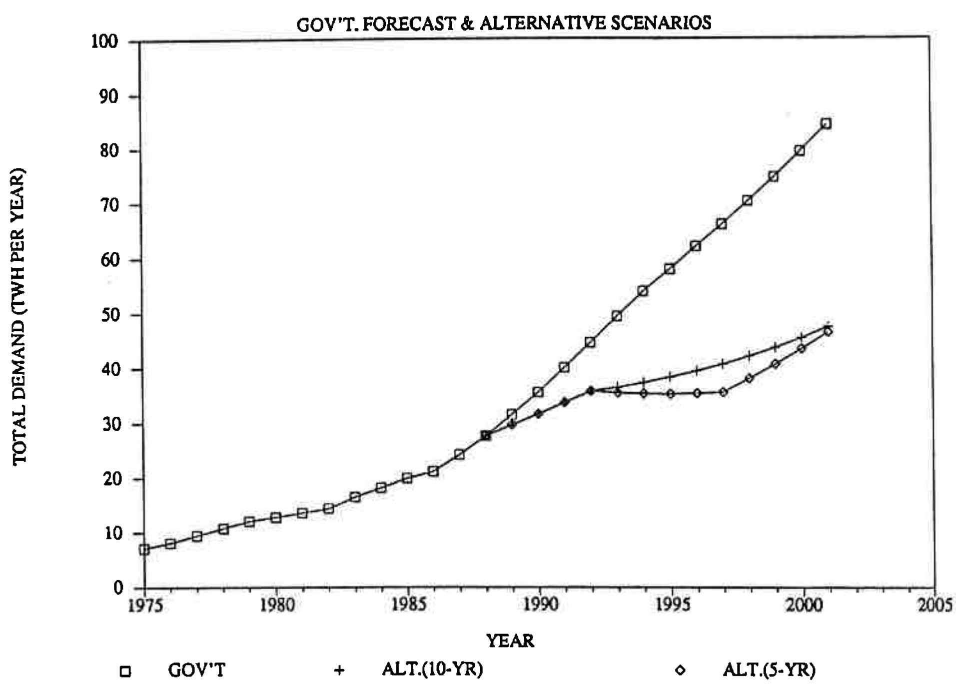

Fig. S.1. Thai government electricity demand forecast to 2001 (from [2]) and alternative energy-efficiency-based scenarios developed from an exercise at the Workshop on End-Use-Oriented Energy Analysis (see [5]). ALT.(10-YR) and ALT.(5-YR) refer to scenarios in which energy efficiency measures are assumed to penetrate into the economy more slowly or more rapidly, respectively.

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* E.D. Larson, E. Mills, L. Nilsson, A.K.N. Reddy, R.H. Williams, S. Nadel and J. Busch, ***Spreadsheet Exercises for the 1989 Thailand Workshop on End-Use-Oriented Energy Analysis***, International Institute for Energy Conservation, Washington, DC and Bangkok, April 1990. (Diskette copies of the spreadsheets are also available.)

1. THE WORKSHOP CONTEXT

1.1. Thailand's Electricity Situation

The Workshop on End-Use-Oriented Energy Analysis was held as Thailand and many other developing countries face major economic and environmental challenges in trying to meet the rapidly growing energy needs of their people. A major economic concern is the growing capital requirements for power sector expansion. Capital investments in 1980 in the power sector totaled 1.5% of GDP on average for all developing countries. The World Energy Conference (WEC) estimates that this figure will grow to between 2.6% and 5.5% in 2000, for a corresponding growth in electricity demand averaging 4.5 and 6.8% per year, 1980-2000. Such massive capital requirements for power-sector expansion would divert financial resources from other development needs, if the resources are available at all. In the environmental area, the global warming associated with continued burning of fossil fuels is receiving prominent worldwide attention. Emissions of carbon dioxide from fossil fuel use in all developing countries today represents only about 1/4 of global CO_2 emissions (Fig. 1). With continued expansion of fossil fuel use assuming "business-as-usual" conditions over the next century, however, developing countries are projected to account for the majority of global CO_2 emissions (Fig. 2). The expansion of fossil fuel use in Thailand as given in official government forecasts would lead to a tripling of per-capita carbon emissions between now and 2000. Thai emissions would then be somewhat higher than half the current world average of about 1.3 tonnes per capita.

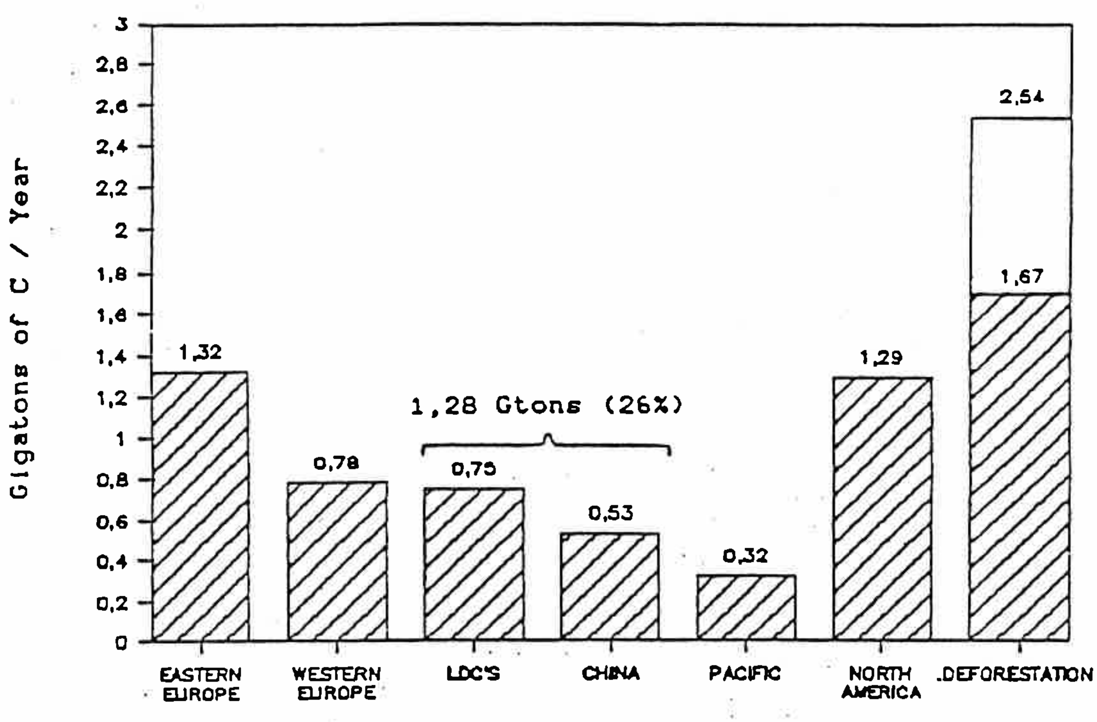


Fig. 1. Estimated annual global emissions of carbon dioxide by source. The estimated contribution from deforestation includes a range of uncertainty. Source: T.B. Johansson lecture at the workshop.

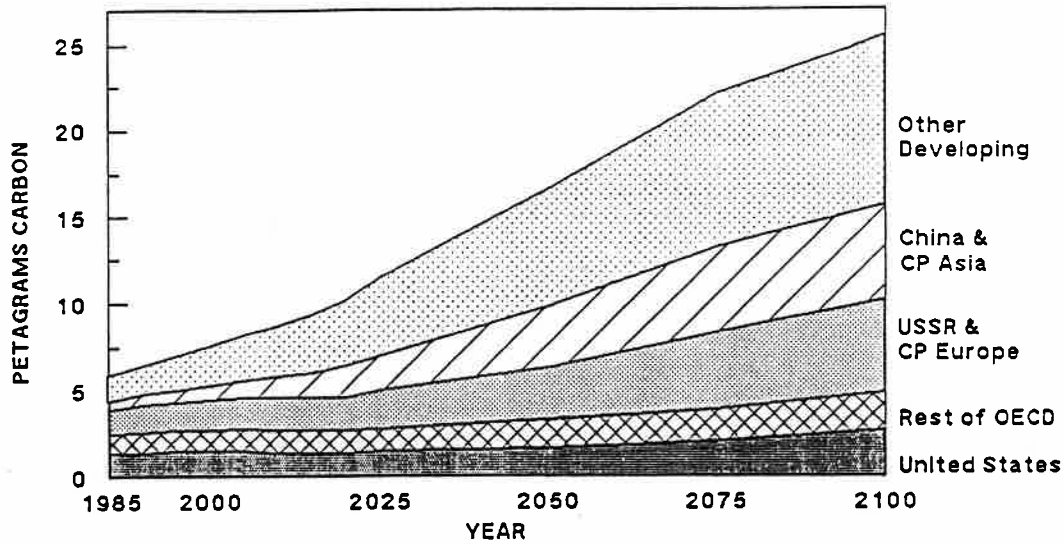


Fig. 2. Estimated carbon dioxide emissions by region over the next century, assuming a "business-as-usual" scenario [1].

The electricity situation in Thailand reflects those in many rapidly industrializing countries. Unexpected strength in the economy has prompted increased manufacturing investment, new commercial building (especially in the tourist, office and high-rise residential sectors), a growing service sector, and has led to overall rising incomes. As a result, Thailand is facing an electricity crisis. The growth in demand for electricity has been nearly twice as large as that forecast by government planners in the last national plan. Electricity demand has nearly tripled in the last decade. The generating reserve margin on some 7200 megawatts of installed capacity has reached a dangerously-low 3-5%. Government forecasts show demand growing 12-14% per year for the next two to four years, with growth averaging 10% per year between 1980 and 2000 [2]. Such growth rates would be far higher than assumed in the WEC calculations (Table 1), suggesting that Thailand will need capital resources far in excess of the average needs estimated by the WEC for all developing countries.

It has become clear that the state-owned Electricity Generating Authority of Thailand (EGAT) will not on its own be able to meet forecast electricity demand over the next decade. Strict ceilings set by the government on the level of foreign debt directly limit EGAT's ability to capitalize all the new generation which would be required to meet the forecast load growth. In recognition of these capital constraints, EGAT has begun to respond more positively to the development of independently generated power. A regulatory structure is being developed to accommodate private power producers, and purchase prices for these new electricity supplies are expected to be established sometime in 1990.

1.2. Energy Efficiency Initiatives in Thailand

The potential for improved end-use efficiency to help deal with the electricity crisis is also starting to be explored. End-use analysis is now being used to a limited extent in load forecasting. The Load Forecasting Working Group (LFWG), a consortium of electric utility and government organizations, was established to develop detailed

Table 1. Alternative scenarios of growth in GDP, electricity demand, and power-sector capital investment requirements for all developing countries and for Thailand (a).

GDP AND ELECTRICITY DEMAND GROWTH RATES (%/year):

	1980-2000 (low case)		1980-2000 (high case)	
	Average for developing countries	*Thailand*	*Average for developing countries*	*Thailand*
GDP (%/yr)	3.5	6.8	4.5	7.3
Electr. demand (%/yr)	4.5	9.6	6.8	10.1

POWER-SECTOR CAPITAL INVESTMENTS AS PERCENTAGE OF GDP:

	1980 (actual)	2000 (low)	2000 (high)
All developing countries	1.5	2.6	5.5
Thailand	1.7	?	?

(a) The numbers shown here for all developing countries are from alterntive scenarios developed by the World Energy Conference [3]. Those for Thailand are from [2], except for the 1980 capital expenditure estimate, which is from [4].

forecasts of electricity demand for Thailand. The LFWG issued its most recent annual load forecast report in October 1989 [2]. Except for the residential sector, the load forecast to 2001 was made using regression correlations of historical electricity use against GDP and electricity price. This econometric approach may have been used in part because sufficient end-use data were not available to formulate more end-use-oriented forecasts. For the residential sector, for which a significant amount of end-use data are available, the LFWG forecast demand using an end-use methodology. However, it assumed no improvements occur between 1988 and 2001 in the energy efficiency of residential appliances. The stated reason for this assumption was a lack of information about possible changes.

The overall result of the LFWG work is that electricity demand is forecast to grow through the turn of the century at roughly the same rate (9-10% per year) as in the decade ending in 1988. Demand is forecast to more than triple, 1988-2001, to some 84,300-93,500 million kWh, corresponding to a GDP-elasticity of 1.5-1.6. An exercise carried out at the End-Use Analysis Workshop to explore alternative future electricity scenarios for Thailand indicated that a much lower GDP elasticity of demand could be achieved through increased emphasis on energy efficiency improvements. For these alternative scenarios, the electricity demand in 2001 would be about half that forecast by the LFWG (Fig. 3), corresponding to a GDP-elasticity of about 0.7. The analysis behind the workshop scenario [5] can be refined considerably, but the results suggest that there are significant end-use efficiency improvements that could be made cost-effectively to reduce the need for new generating capacity in Thailand. Scenario analyses such as shown in Fig. 3 could be used as the basis for developing policies and programs to achieve electricity savings in practice in Thailand.

While the LFWG has not yet explicitly incorporated end-use efficiency policies or programs into their load forecasts, electricity conservation is beginning to receive some attention from the National Energy Administration. Its Electricity Savings Plan, which has been approved by the National Energy Policy Committee, calls for a national savings of 159 megawatts of generating capacity over a three year period beginning in

1990. This represents about 1% of the load growth forecast by the LFWG for this period. The plan includes recommendations for public education programs, appliance efficiency standards, commercial building energy standards, and lowering import tariffs on energy-efficient equipment. Specific mechanisms for implementing the Plan are now being developed.

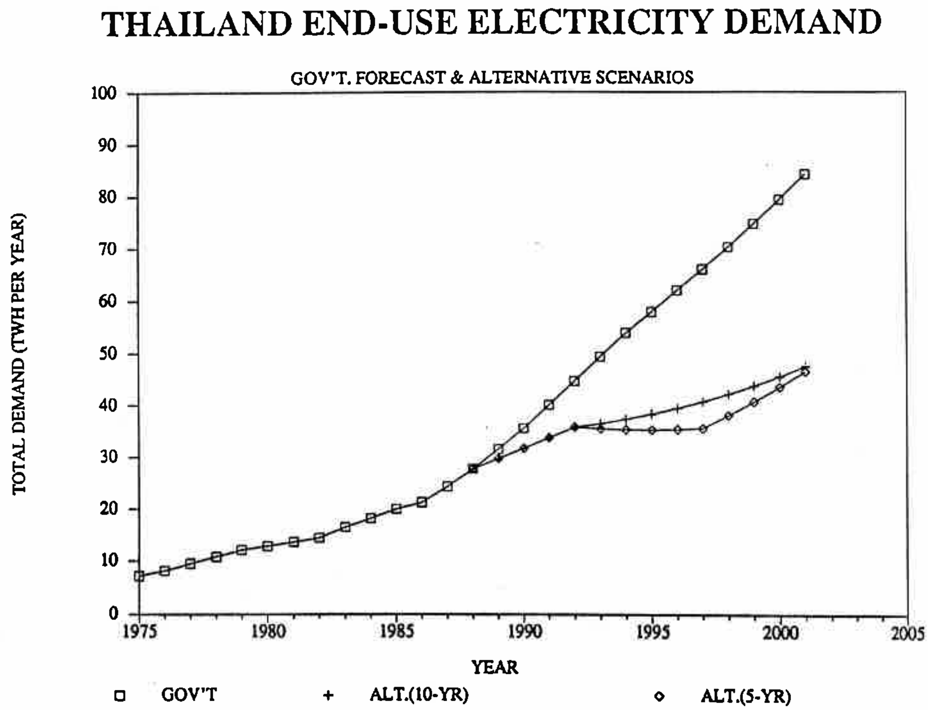


Fig. 3. Thai government electricity demand forecast to 2001 (from [2]) and alternative energy-efficiency-based scenarios developed from an exercise at the Workshop on End-Use-Oriented Energy Analysis (see [5]). ALT (10-YR) and ALT (5-YR) refer to scenarios in which energy efficiency measures are assumed to penetrate into the economy more slowly or more rapidly, respectively.

1.3. Motivation for the Workshop

The growing interest in energy efficiency in Thailand is in part a result of the 1988 conference, "Energy Efficiency Strategies for Thailand: the Needs and the Benefits," which helped establish the viability of the conservation approach by presenting successful implementation case studies from around the world [6]. The conference was organized by the Thai Ministry of Science, Technology and Energy, the Federation of Thai Industry, King Mongkut's Institute of Technology, Chulalongkorn University, the Asia Pacific Regional Office of the United Nations Environment Program, and the International Institute for Energy Conservation (IIEC).

Among the conclusions reached at that conference was that a key barrier to increased end-use energy efficiency in Thailand--as in many other developing countries--was a lack of indigeneous capability to treat energy efficiency analytically on a par with energy supply. Without this capability, planners lack the means for integrating energy efficiency strategies into energy planning. As a result, such strategies are typically accorded minor, extraneous roles outside of the thrust of energy planning activities. To help address this problem the members of the organizing committee for that conference recommended that a high priority be given to undertaking a series of training seminars to develop greater in-country expertise in various aspects of end-use energy efficiency. In particular, it was agreed that such seminars should offer training in end-use-oriented energy analysis. Such training is needed to undertake the analytical studies needed to identify cost-effective energy conservation opportunities, to integrate energy efficiency with energy supply in "least-cost" energy plans, and to develop policies and programs for implementing energy efficiency.

The training workshop described in this document was undertaken as part of the IIEC's "model-country" program activities in Thailand. Under this program, the IIEC undertakes a long-term effort to help foster a major commitment to energy efficiency in the relevant country. The IIEC maintains its Asia office in Bangkok. Thus, the IIEC-Asia staff were able to work closely with the Thai co-organizer of the workshop, Dr. Woraphat Arthayukti, to tailor the program to Thai needs and to identify and engage the participation of key energy analysts and planners from most of the energy-related institutions in Thailand. The workshop was successful in large part because of this close collaboration between the Thai and non-Thai organizers.

1.4. Objectives of the Workshop

The main objective of the Thailand workshop was to inform and train Thai analysts, planners and policy-makers in the government, electric utilities and universities in energy end-use analysis techniques. Electricity was chosen as the focus for the workshop because of the current intense interest in this energy carrier in Thailand. For representatives of the government and electric utilities, the seminar was intended to provide the tools needed to more fully incorporate energy efficiency into their future electricity planning. For the academic community, the seminar was designed both to transfer analytical skills and to provide the basis for developing university curricula in energy end-use analysis, through which future Thai energy decision makers could be trained.

A second objective of the workshop was to begin development of an end-use data base to further the understanding of electricity end-use in Thailand, which in turn would facilitate the design, analysis, implementation and monitoring of electricity conservation programs.

A third objective of the workshop was to use the experience in Thailand to develop a "model" end-use analysis teaching seminar, which would provide the basis for developing similar training workshops for other countries.

2. ORGANIZERS AND SPONSORS

The Workshop was co-organized by Woraphat Arthayukti (Energy Research and Training Center, Chulalongkorn University, Bangkok), Deborah Bleviss (International Institute for Energy Conservation, Washington, DC), Mark Cherniack (International Institute for Energy Conservation, Bangkok), and Eric Larson (Center for Energy and Environmental Studies, Princeton University, USA). The Energy Research and Training Center at Chulalongkorn University provided the site and administrative support for the workshop. The International Institute for Energy Conservation (Washington office) provided primary funding for the workshop. Additional financial support was provided by the US Agency for International Development (Washington, D.C.), the Swedish Institute (Stockholm), and the Department of Environmental and Energy Systems Studies, Lund University (Lund, Sweden).

3. PARTICIPANTS, INSTRUCTORS AND PROGRAM

The workshop ran for 10 days, with a 3-hour morning and 3-hour afternoon session on each day. An international group of instructors gave lectures in the mornings. The afternoons were devoted to hands-on work with spreadsheet exercises using personal computers. The complete set of spreadsheet exercises have been compiled in a separate document [5].

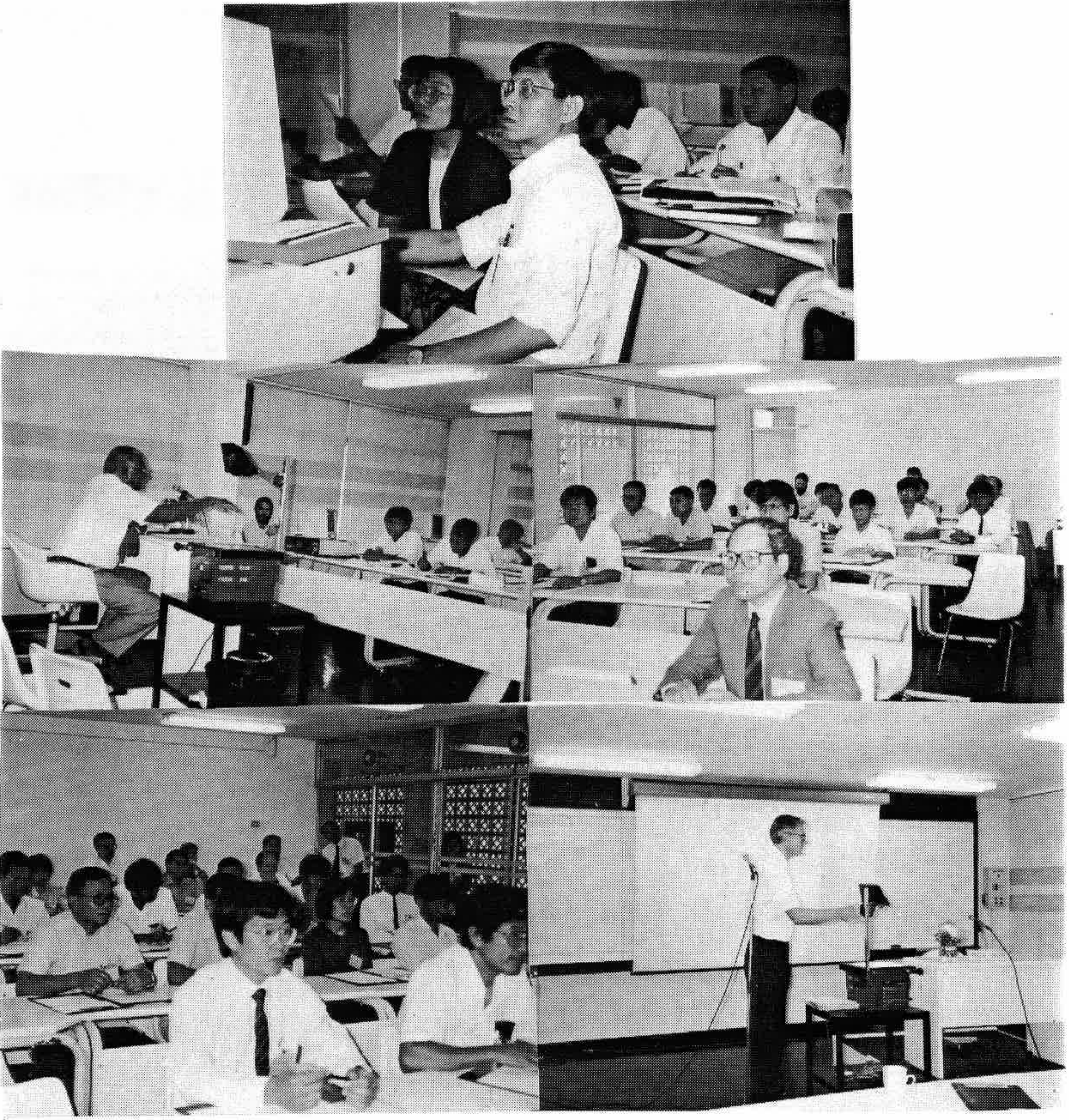
Approximately half of the Thai participants were from the government and electric utilities and half were from Thai universities. They included analysts and planners from the National Energy Policy Office (NEPO), the National Energy Administration (NEA), the Electricity Generating Authority of Thailand (EGAT), the Provincial Electricity Authority (PEA), the Energy Conservation Center of Thailand (ECCT), the Thailand Development Research Institute (TDRI), the Siam Cement Company, and professors from Chiangmai, Chulalongkorn, Kasetsart, Khon Kaen, and Prince of Songkla Universities and King Mongkut's Institute of Technology at Bangkok and Thonburi. A complete list of the participants is given in Appendix A.

As detailed in Appendix B, the instructors included Professor Amulya Reddy (Indian Institute of Science, Bangalore), Professor Roberto Moreira (University of Sao Paulo, Brazil), Professor Thomas B. Johansson, Evan Mills and Lars Nilsson (Lund University, Sweden), Dr. Mark Levine and John Busch (Lawrence Berkeley Laboratory, USA), Dr. Robert H. Williams and Dr. Eric D. Larson (Princeton University, USA) and Steven Nadel (American Council for an Energy-Efficient Economy, USA).

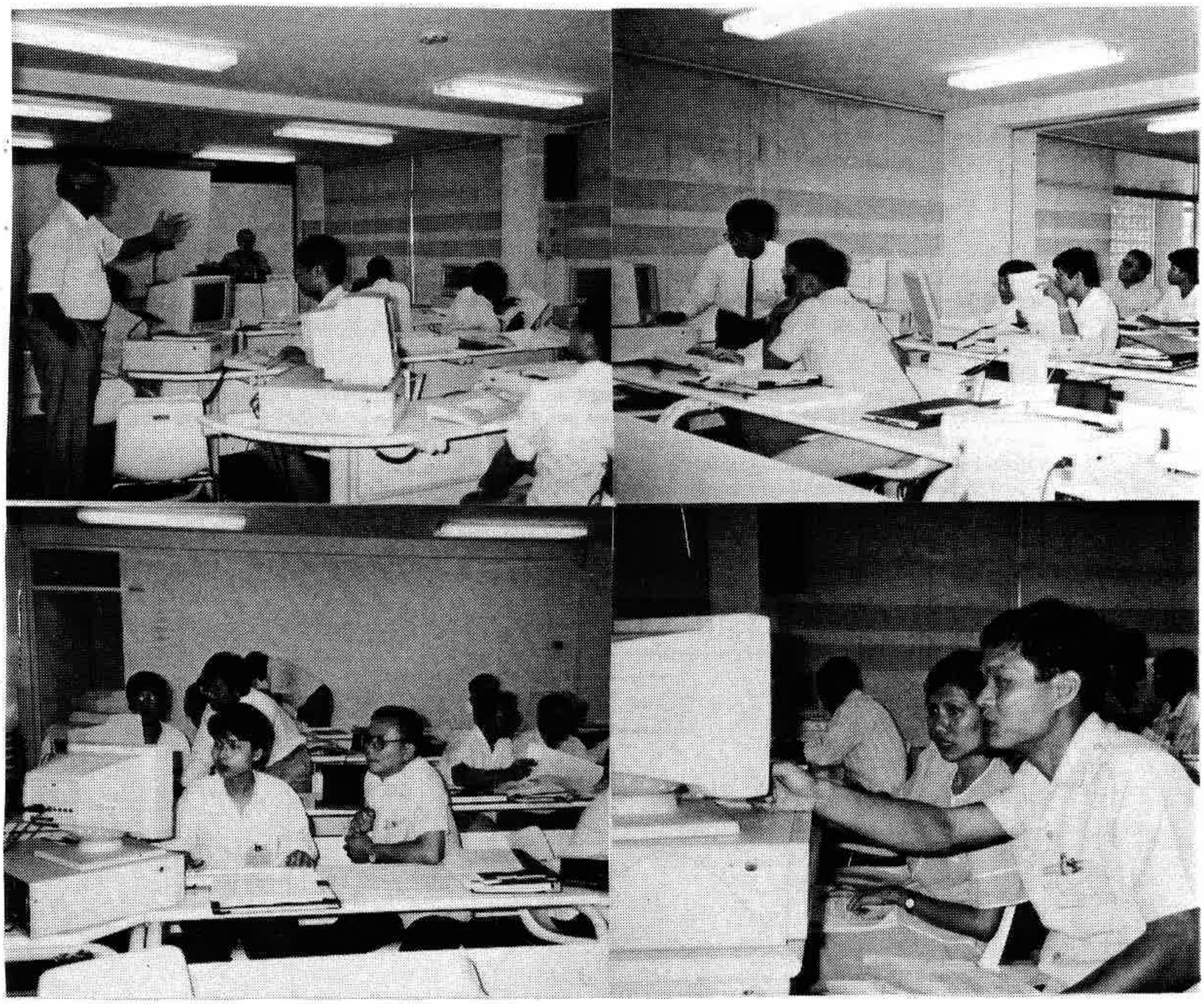
As summarized in the daily workshop program (Appendix C), the morning lectures addressed a range of topics relating to end-use analysis, including methodologies of technical and economic end-use analysis of electricity conservation, electricity use in industry and buildings, new energy efficient technologies, cogeneration and other new electricity supply technologies, cost-assessment of electricity supply, rural electrification, alternative scenarios of future electricity demand for India and Brazil, least-cost planning, and implementation of electricity conservation programs. A summary of the lectures is provided in Section 4 below. During the afternoon sessions, the participants worked with prepared spreadsheets to undertake end-use-oriented analyses related to the morning lecture topics. The participants worked in teams on the computers (see photographs below). On the final full day of the workshop they made short presentations of some of their analytical work.

Each participant received a set of resource materials, including the primary text for the workshop, ***Energy for a Sustainable World*** [7]. At the close of the workshop a reference collection was established at King Mongut's Institute of Technology Thonburi (KMITT) containing a single copy of all of these materials, as well as a number of documents relating to Thailand's energy use. The latter documents were assembled before the workshop and used to help develop the spreadsheet exercises. The KMITT reference collection is under the care of Miss Warunee Tia, one of the workshop participants. It constitutes an initial data base that workshop participants and others can draw on to assist in end-use-oriented analyses. Appendix D lists all materials that were available at the workshop and which are now in the KMITT collection.

Opening statements welcoming all participants to the workshop and describing ongoing activities in energy conservation in Thailand were made by Professor Woraphat Arthayukti, from Chulalongkorn University (upper left), Pinij Gritiyaransan, Director of the Energy Conservation Center of Thailand (upper right), Dr. Charuay Boonyubol, Director of the Energy Research and Training Center at Chulalongkorn University, which hosted the workshop (lower left) and Mark Cherniack, Director of the Asia Office (Bangkok) of the International Institute for Energy Conservation.



Workshop participants heard morning lectures given by an international group of instructors, including Professor Amulya Reddy from the Indian Institute of Science, Bangalore (middle left) and Professor Thomas B. Johansson from the Department of Environmental and Energy Systems Studies, Lund University, Sweden (lower right).



During the afternoon sessions, participants worked with each other and the instructors to undertake end-use-oriented energy analyses relevant to Thailand. They worked in teams using personal computer spreadsheet software.

4. SUMMARY OF WORKSHOP LECTURES

The workshop lectures are summarized here. The accompanying figures represent a sampling of the overhead transparencies shown at the workshop.

4.1. Motivation and Methodology

Overview and Methodology of End-Use-Oriented Energy Analysis
- T.B. Johansson

Continued growth in the demand for energy at historical rates would exacerbate some major global problems: environmental degradation due to the greenhouse warming associated largely with the combustion of fossil fuels; international security associated with overdependence on Middle-East oil; nuclear weapons proliferation risks and reactor accidents associated with overdependence on nuclear power, and continuing poverty and underdevelopment in developing countries due in part to high costs for energy supply (e.g. oil imports and new power plant construction).

Application of end-use-oriented energy analysis can help identify national strategies that would be consistent with the solution of such major global problems and that would lead to an increase in the services that energy provides (cooled air, refrigerated foods, personal transport, industrial production, etc.), without the need for a corresponding increase in energy supplies. Some strategies of this type have been pursued in some industrialized countries since the oil-price shocks of the 1970s and have led to a decoupling of historic energy demand/GDP relationships, as illustrated for the OECD in Fig. 4, and to continually lower projections of future energy demands, as Fig. 5 shows for the USA.

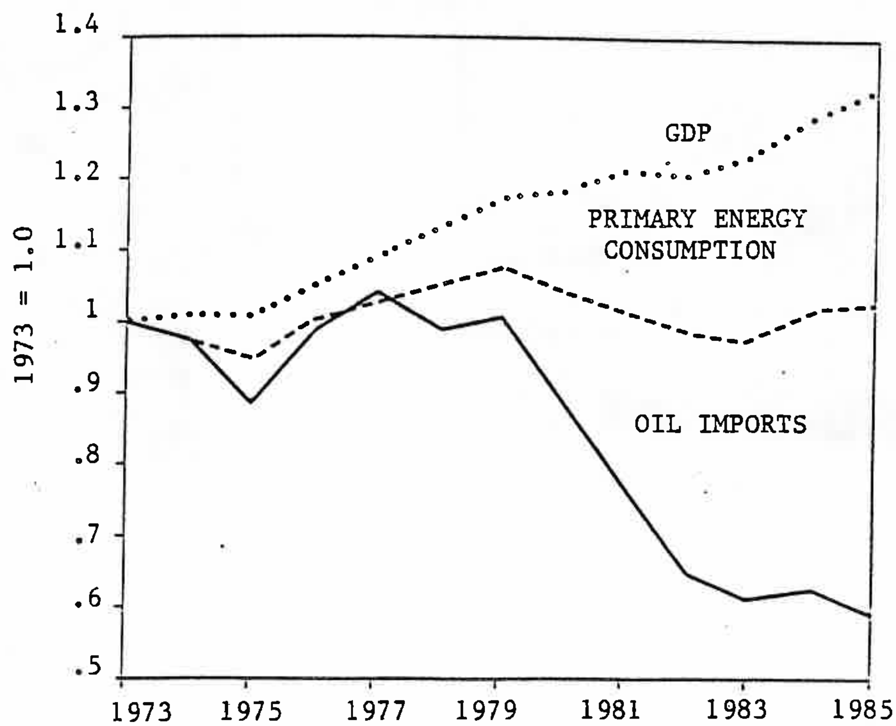


Fig. 4. Primary energy consumption, net oil imports, and gross domestic product for OECD countries relative to the values of these quantities in 1973 [8].

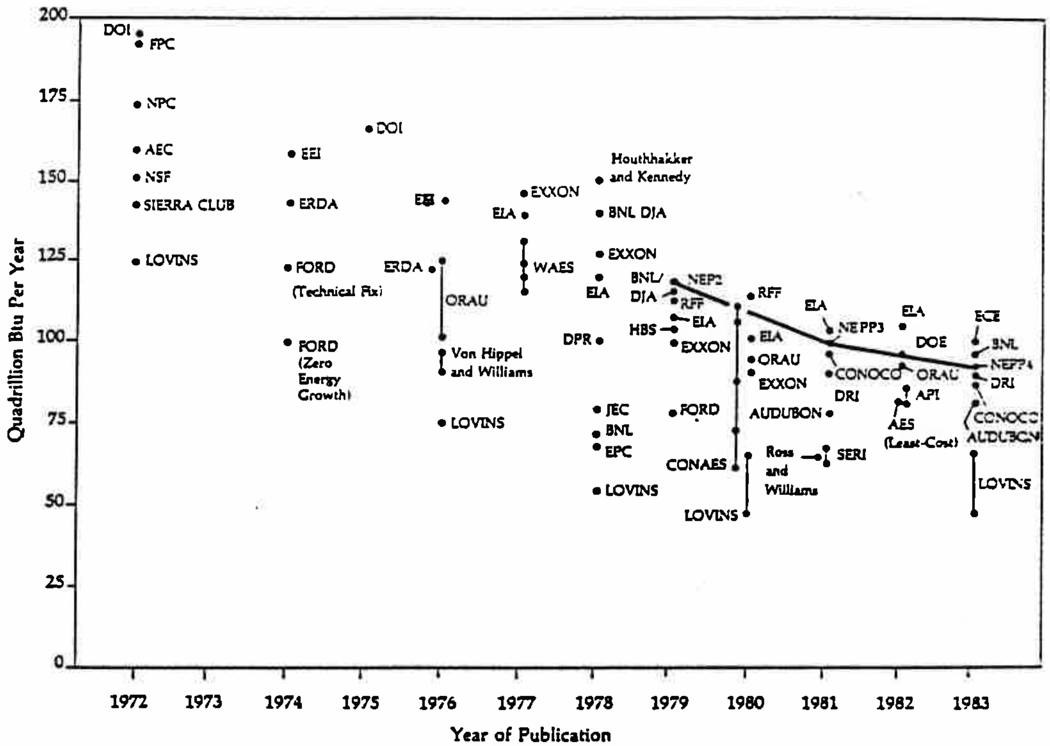


Fig. 5. Forecasts of United States primary energy requirements for the year 2000 versus the years the forecasts were made [8].

Developing national end-use-oriented scenarios of future energy demand involves detailed analysis of all major energy consuming activities in a society. Total energy use is then determined simply as the sum of energy use in all activities:

$$\text{Total Energy Demand} = \sum_i \{(\text{activity level})_i \times (\text{energy intensity})_i\}$$

where the activity level refers to the service level provided (e.g. person-km of transport, cooled m^2 of building space, tonnes of steel production, etc.) and the energy intensity is the specific energy use associated with each activity (e.g. GJ/person-km, kWh/m^2, GJ/tonne steel, etc.) Understanding existing patterns of energy end-use, together with the range of energy-using technologies that are or will become available permits scenarios of possible future energy demands to be developed. Appropriate energy policies can then be developed to help steer the economy toward the scenarios that are most attractive.

An example of such a scenario is a thought experiment undertaken to explore the potential energy use in a hypothetical developing country in the year 2020 [5]. The activity levels are assumed to be those that correspond to the standard of living in Western Europe in the mid-1970s (Fig. 6), and the intensities are based on the best commercially available or prototype technologies and industrial processes (Fig. 7). With these activity levels and intensities, the average rate of final energy use in such a developing country in 2020 would be about 1 kW per capita (Fig. 8), or only slightly higher than the current energy use level (Fig. 9). Such a hypothetical scenario suggests that there can be a more hopeful energy future for many countries now facing the prospect of energy shortages than is presently forecast.

Activity	Activity Level
Residential[b]	4 persons per household
Cooking	Typical cooking level with LPG stoves[c]
Hot water	50 liters of hot (50°C) water per capita per day
Refrigeration	1 315-liter refrigerator-freezer per household
Lights	New Jersey (United States) level of lighting
TV	1 color TV per household, 4 hours per day
Clothes washer	1 per household, 1 cycle per day
Commercial[e]	5.4 m^2 of floor space per capita
Transportation[e]	
Cars	0.19 cars per capita, 15,000 km per car per year
Intercity Bus	1,850 passenger-kilometers per capita per year
Passenger Train	3,175 passenger-kilometers per capita per year[d]
Urban Mass Transit	520 passenger-kilometers per capita per year[f]
Air Travel	345 passenger-kilometers per capita per year
Truck Freight	1,495 tonne-kilometers per capita per year
Rail Freight	814 tonne-kilometers per capita per year
Water Freight	50 percent of OECD Europe average in 1978[g]
Manufacturing	
Raw Steel	320 kg per capita per year (OECD Europe average, 1978)
Cement	479 kg per capita per year (OECD Europe average, 1980)
Primary Aluminum	9.7 kg per capita per year (OECD Europe average, 1980)
Paper and Paperboard	106 kg per capita per year (OECD Europe average, 1979)
Nitrogen Fertilizer	26 kg nitrogen per capita per year (OECD Europe average, 1979–1980)
Agriculture	WE/JANZ average for 1975
Mining, Construction	WE/JANZ average for 1975

Fig. 6. Activity levels for a hypothetical developing country having energy amenities (except space heating) like those in Western Europe in the 1970s [9].

Activity	Technology, Performance
Residential	
Cooking	70 percent efficient gas stove[b]
Hot Water	Heat pump water heater, coefficient of performance = 2.5[c]
Refrigeration	Electrolux refrigerator-freezer, 475 kWh per year
Lights	Compact fluorescent bulbs
TV	75-Watt unit
Clothes Washer	0.2 kWh per cycle[d]
Commercial	Performance of Harnosand building in Sweden (all uses, except space heating)[e]
Transportation	
Automobiles	Cummins/NASA Lewis car at 3.0 liters per 100 km[f]
Intercity Bus	75 percent of WE/JANZ energy intensity in 1975[g]
Passenger Train	75 percent of WE/JANZ energy intensity in 1975[h]
Urban Mass Transit	75 percent of WE/JANZ energy intensity in 1975[i]
Air Travel	50 percent of U.S. energy intensity in 1980[j]
Truck Freight	0.67 MJ per tonne-kilometer[k]
Rail Freight	Electric rail at 0.18 MJ per tonne-kilometer[l]
Water Freight	60 percent of OECD energy-intensity[m]
Manufacturing	
Raw Steel	Average, Plasmasmelt and Elred processes
Cement	Swedish average in 1983[n]
Primary Aluminum	Alcoa process[o]
Paper and Paperboard	Average of 1977 Swedish designs[p]
Nitrogen Fertilizer	Ammonia derived from methane[q]
Agriculture	75 percent of WE/JANZ energy intensity in 1975[r]
Mining, Construction	75 percent of WE/JANZ energy intensity in 1975[r]

Fig. 7. Assumed end-use technologies and their energy performance levels for energy-using activities for a hypothetical developing country [9].

Activity	Average Rates of Energy Use (Watts per capita) Electricity	Fuel	Total
Residential			
Cooking		34	
Hot Water	29.0		
Refrigeration	13.5		
Lights	3.8		
TV	3.1		
Clothes Washer	2.1		
Subtotal	51	34	85
Commercial	22		22
Transportation			
Automobiles		107	
Intercity Bus		26	
Passenger Train	4.5	32	
Urban mass Transit	2.0	8	
Air Travel		21	
Truck Freight		32	
Rail Freight	5		
Water Freight (Including Bunkers)		50	
Subtotal	12	276	288
Manufacturing			
Raw Steel	28	77	
Cement	6	54	
Primary Aluminum	11	26	
Paper and Paperboard	11	24	
Nitrogen Fertilizer		36	
Other[b]	65	212	
Subtotal[c]	121	429	550
Agriculture	4	41	45
Mining, Construction		59	59
Total	210	839	1 049

Fig. 8. Final energy-use scenario for the hypothetical developing country [9]. See Figs. 6 and 7.

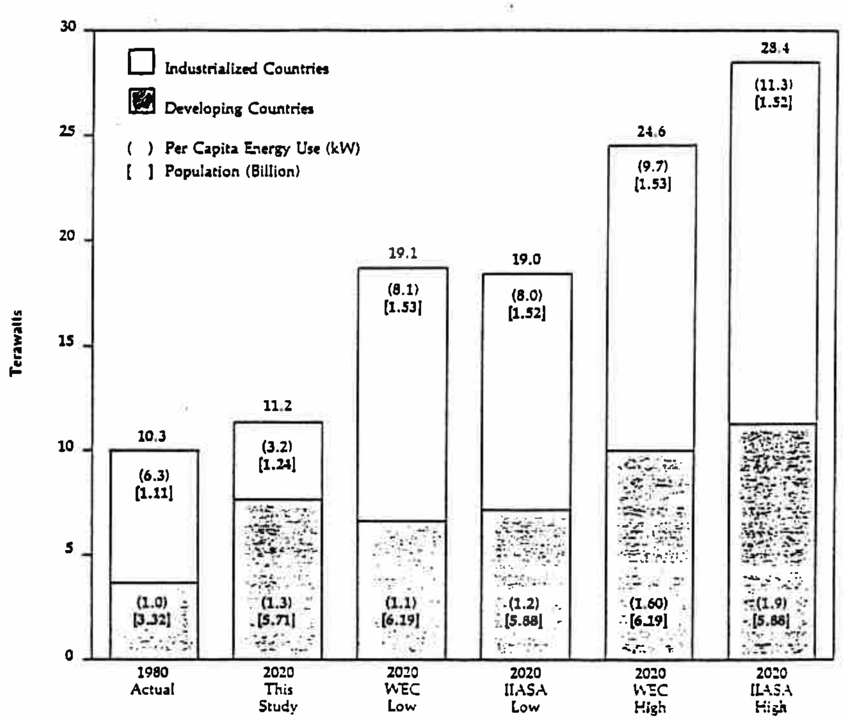


Fig. 9. Alternative projections of global primary energy use (in terawatt-years per year) disaggregated into shares accounted for by the industrialized and developing countries. WEC refers to the 1982 World Energy Conference, IIASA to a 1981 study by the International Institute for Applied Systems Analysis, and This Study to [8].

Such scenarios would involve large capital investments, as would be the case in expanding energy supplies. However, there is a broad base of experience in industrialized countries that indicates that the extra capital required to purchase energy-efficient technology that would save a kW of energy (i.e. the cost of saved energy) is often lower than the cost to supply an incremental kW to fuel a less-costly, but also less-efficient technology. The difference in capital required to save and supply a kW is often larger the higher the discount rate (e.g., see Fig. 10). Thus, energy efficiency improvement should be of particular interest in many developing countries, where discount rates are typically higher than in industrialized countries.

An additional factor to consider for developing countries is the need for "technological leapfrogging." Many energy-using technologies and processes developed in the industrialized countries are capital intensive and labor efficient, characteristics that are often inappropriate in developing countries. And developing countries have greater needs for some energy services than in industrialized countries (e.g. space cooling). Thus, some technologies developed for industrialized countries may be inappropriate for developing countries. Technological leapfrogging refers to the development of new, innovative technologies and processes that are compatible with local resources and are also supportive of broad development goals. One example is the steel industry in Brazil, which has introduced charcoal-based processes to produce world-class steel competitively. The charcoal-based process requires greater labor, is less capital intensive, and uses to competitive advantage a climate ideally suited to growing the biomass feedstocks needed for charcoal production.

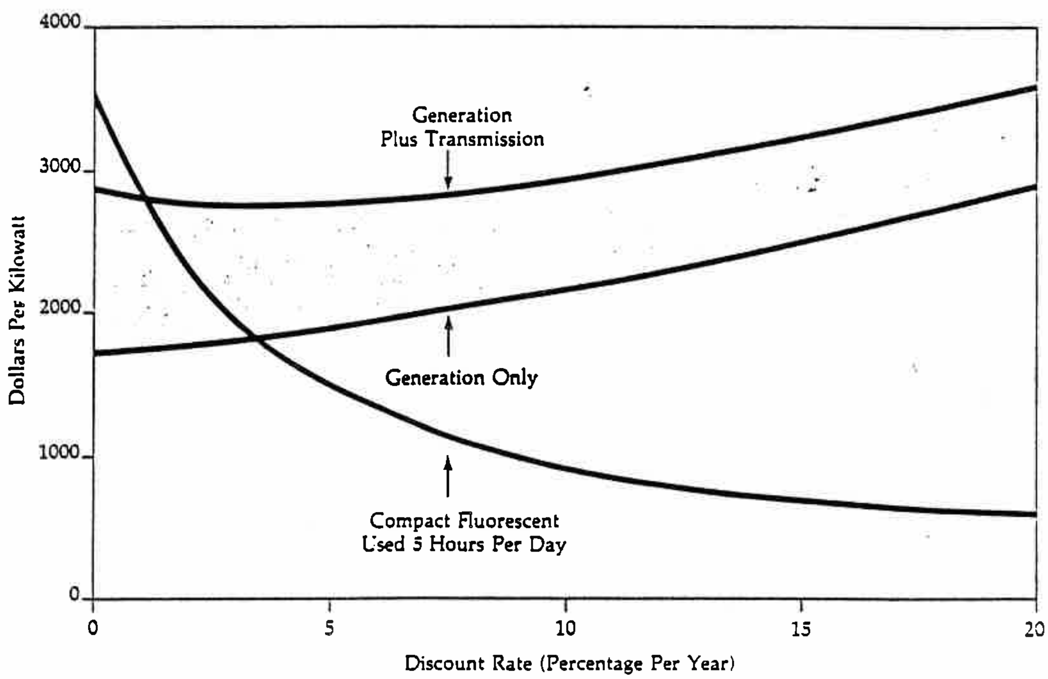


Fig. 10. Life-cycle costs for providing peaking hydroelectric power in Brazil and for saving electricity through use of compact fluorescent bulbs as alternatives to incandescents. The cost of hydropower supplies increases with the discount rate because of interest charges accumulated during construction. The cost of more efficient lightbulbs declines with the discount rate because replacement bulbs need not be purchased until they are needed [9].

Scenario Building

- E. Mills

Energy scenario building should be an integral part of "least-cost" energy planning, in which the costs of saving energy are compared on an equal basis with the costs of supplying energy (e.g. using the same discount rate), and efficiency or supply measures are implemented in order of increasing cost. The development of conservation supply curves analogous to energy supply curves, is useful in quantifying the "demand-side resources" for different scenarios. Conservation supply curves can be developed at the micro level, e.g. Fig. 11 shows the incremental cost (cents/kWh) and corresponding energy savings estimated for improving the efficiency of a refrigerator/freezer. Conservation and energy supply curves can be integrated to identify the total energy services available by saving or supplying energy and the "least-cost" ordering of these. For example, Fig. 12 is an integrated resource supply curve for an electricity scenario developed for Sweden.

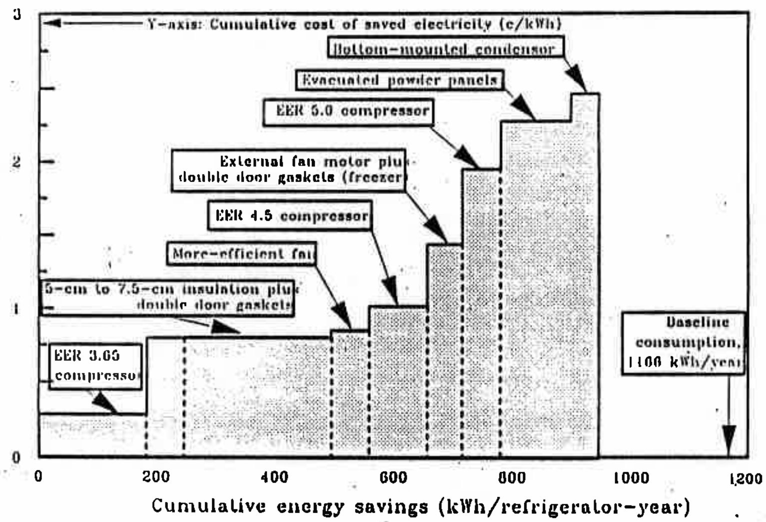


Fig. 11. Example micro supply curve of saved energy: for US-made, top-mounted, auto-defrost refrigerator/freezer. Source: E. Mills lecture at the workshop.

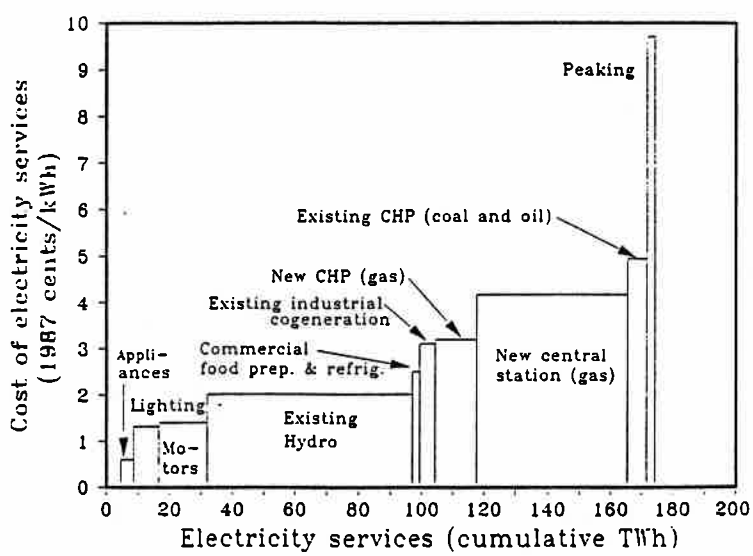


Fig. 12. Sample integrated resource supply curve for an electricity scenario for Sweden [10].

An important concept in scenario-building is the "frozen-efficiency" base-line, which is the scenario developed by combining today's energy intensities with activity levels and structural changes projected for the future scenario year. The energy demand in the frozen-efficiency scenario represents the level of energy services expressed in energy units (e.g., kWh used for lighting) rather than service units (e.g., lumens of light). Expressing energy services in this way permits energy savings (through adoption of more energy-efficient technology) to be readily quantified when efficiency improvements are considered in "efficiency" scenarios. A series of such efficiency scenarios can be developed assuming different levels of average energy intensities for various activities. Fig. 13 shows different levels of estimated annual energy use in residential appliances and fluorescent ballasts which might be used in scenario building.

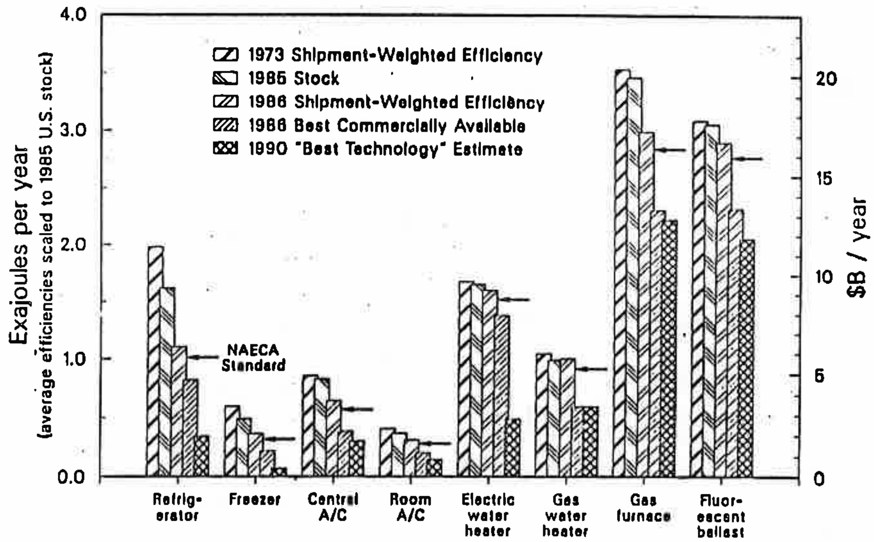


Fig. 13. Trends in US appliance efficiencies. Annual energy use is calculated using the five indicated efficiencies applied to the number of appliances in the 1985 US stock. NAECA refers to the National Appliance Energy Conservation Act recently enacted in the US. Source: E. Mills lecture at the workshop.

4.2. Industrial Energy Use

Promoting Technological Innovation in the Basic Materials Processing Industries in Developing Countries as a Strategy for Quickening the Pace of Economic Development and Improving Industrial Energy Efficiency
- R.H. Williams

The industrial sector in most developing countries accounts for the largest share of total energy use (about 50% in Thailand). The raw materials-processing industries (primary metals, cement, paper, food, petroleum refining, and stone, clay and glass) account for the majority of industrial energy use, but contribute a much smaller fraction to the manufacturing value added in a country. (See following lecture.)

In most industrialized countries the consumption of basic materials per unit of gross national product (GNP) peaked and has gone into decline--in some cases many decades ago--and per-capita consumption has also leveled off (illustrated for the USA in Fig. 14). These trends signal a basic shift in industrialized countries away from material-intensive activities. The situation is quite different in developing countries, where materials consumption is much lower. In 1980, the consumption of basic materials in Japan and the USA was 1800 kg/capita and 1500 kg/capita, respectively, compared to 500 kg/capita in newly industrializing countries and 35 kg/capita in low-income countries like China and India.

The energy-intensive basic materials industries are relatively young in developing countries and can be expected to expand significantly in the future. Since the basic materials industries are generally stagnant or in decline in the industrialized countries, little innovative technology development is occurring that could lead to reduced energy use in these industries in industrialized countries. For developing countries, adopting the energy-intensive processes of the industrialized countries would lead to significantly increased energy use as the industries expand. To avoid this prospect, developing countries could pursue "leapfrogging" strategies to develop low energy-use basic materials processing technologies. Technology policies today typically do not encourage such innovation. For example, current World Bank policy in this area states that

> ...In the world of energy, as in many other areas, (the Bank's) role is not to create innovative technical solutions, or to help countries to gamble on new processes, but to identify the best practices that have been fully proven in practice, and will work in a developing country situation, and encourage their wider adoption where merited by circumstances...

Different technology policies are clearly needed to encourage technological innovation.

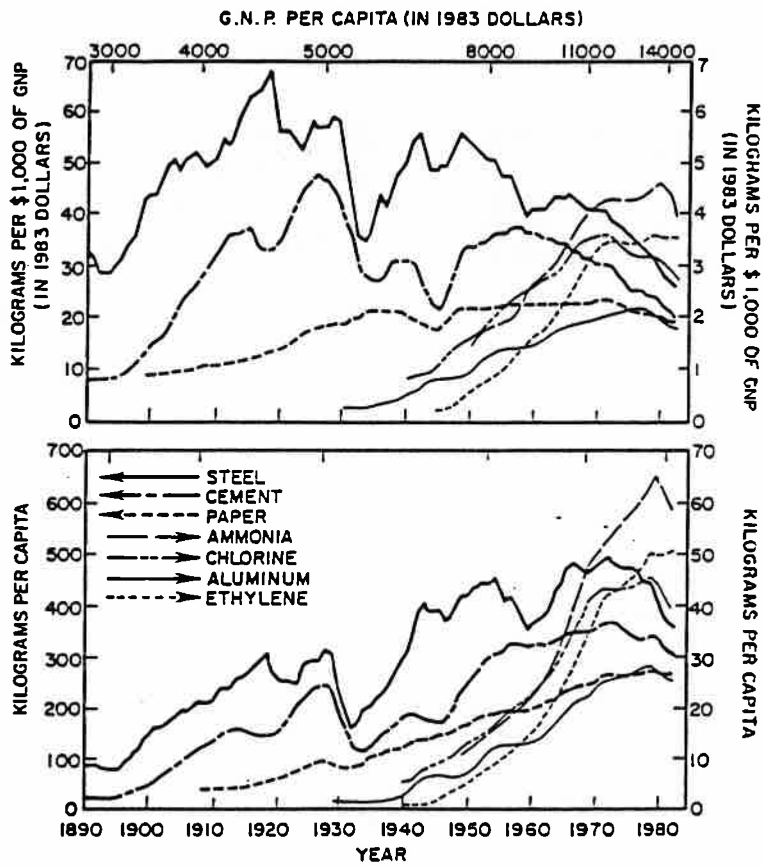


Fig. 14. Trends in consumption per capita (bottom) and consumption per dollar of gross national product (top) in the US for both traditional (steel, cement, paper) and modern (aluminum, ethylene, chlorine, and ammonia) basic materials [11].

Energy and Industry

- J.R. Moreira

The industrial sector accounts for the largest share of energy use in most developing countries--about 50% in Brazil, as in Thailand. Within the industrial sector, the basic materials processing industries account for the largest share of energy use (Fig. 15), but a proportionately much smaller fraction of industrial value added. For example, in Brazil, 3/4 of manufacturing energy use is accounted for by industries providing 1/3 of value added (Fig. 16). The basic materials processing industries are also major users of electricity. Half of electricity use in the relatively electricity-intensive Brazilian industrial sector is accounted for by industries providing only 1/8 of industrial value added (Fig. 17).

Most industrial electricity use is accounted for by motors, as Fig. 18 shows for Brazil. Motors are relatively efficient devices, but because many motors operate for many hours per year, significant quantities of electricity can be saved through use of energy-efficient motors (see next lecture), giving payback times of 1-2 years in many cases (Fig. 19).

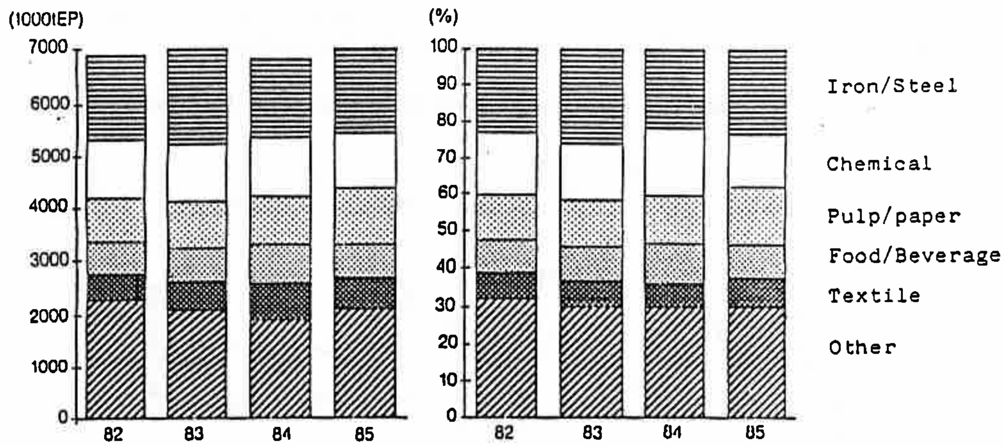


Fig. 15. End-use energy consumption in the Brazilian industrial sector: tonnes of oil equivalent (left) and percent shares (right) [12].

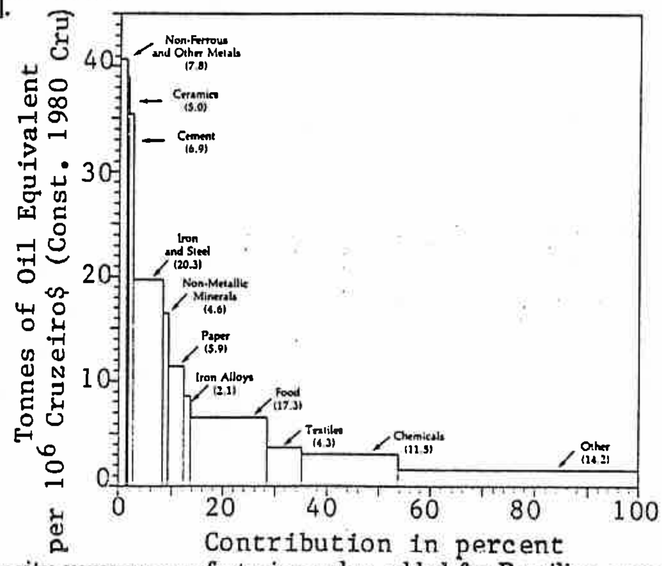


Fig. 16. Final energy intensity versus manufacturing value added for Brazilian manufacturing industries in 1980 [9]. The number displayed for each bar is that sector's percentage contribution to total final energy use in Brazilian manufacturing.

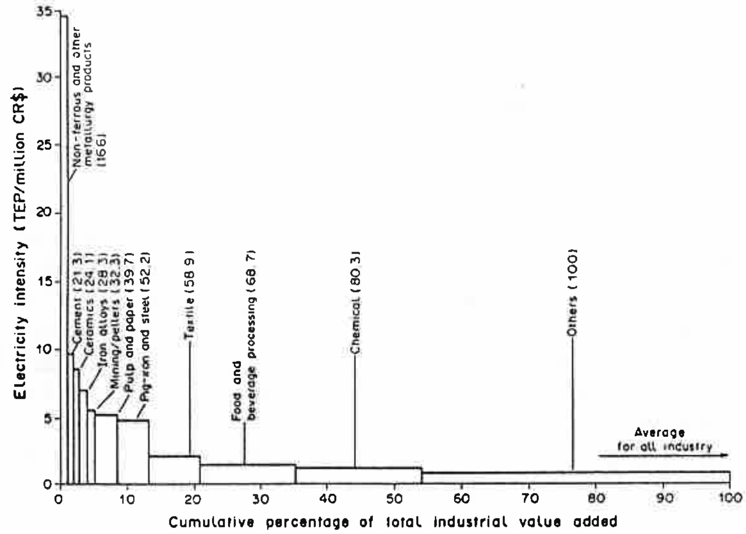


Fig. 17. The electricity intensity of industries in Brazil (1980). Numbers in parentheses correspond to cumulative percentage of total industrial electricity use [13].

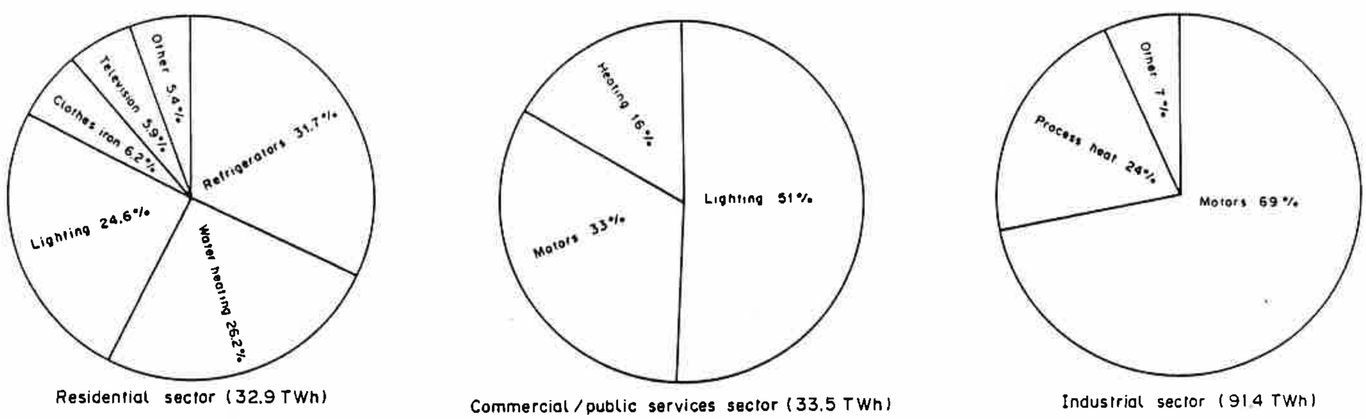


Fig. 18. Electricity demand in Brazil by end use and sector (totals apply to 1985) [13].

No.	Size (HP)	Application	Load (% Rated Size)	Efficiency At This Load %	Power Factor At This Load %	Simple Payback (years)	IRR (%)	Recommendation
1	10	Conveyor	22.9	74.7	40.8	1.4	41.5	Downsize
2	10	Conveyor	23.4	76.9	42.0	1.6	35.9	Downsize
3	10	Screen	78.3	85.8	79.2	2.9	21.8	Replace
4	15	Conveyor	56.8	85.4	61.3	2.0	27.8	Downsize
5	15	Screen	64.9	87.0	71.0	4.2	15.4	Keep this motor
6	15	Pump	93.6	90.4	87.3	5.4	12.1	Keep this motor
7	20	Conveyor	14.8	63.1	49.3	0.6	90.1	Downsize
8	20	Pump	53.0	85.6	64.0	2.4	25.6	Downsize
9	20	Vacuum Pump	101.5	83.1	85.3	1.9	31.8	Replace
10	20	Compressor	112.6	83.1	82.3	1.7	34.3	Replace
11	20	Blower	65.9	83.5	80.4	2.9	21.5	Downsize
12	20	Blower	70.5	87.0	83.5	3.2	20.1	Replace (Margina
13	25	Screen	45.9	85.4	57.0	1.8	32.8	Downsize
14	25	Pump	75.7	92.1	75.0	6.1	10.6	Keep this motor
15	30	Screen	42.4	85.7	67.2	2.0	29.5	Downsize
16	30	Screen	53.2	87.0	77.4	1.9	31.3	Downsize
17	30	Screen	34.3	83.5	60.3	5.9	11.0	Keep this motor
18	30	Pump	87.8	90.9	77.8	2.9	21.8	Replace
19	40	Screen	57.9	85.0	81.0	1.1	50.8	Downsize
20	40	Mixer	65.1	85.3	82.0	1.1	51.4	Downsize
21	40	Screen	48.7	87.1	74.4	1.6	35.9	Downsize
22	40	Screen	48.3	87.8	72.7	1.9	31.9	Downsize
23	40	Pump	75.0	92.0	90.9	3.7	17.5	Keep this motor
24	50	Blower	57.2	89.8	70.7	2.0	29.6	Downsize
25	60	Pump	65.6	90.1	81.1	2.1	28.6	Downsize
26	75	Blower	22.3	81.7	57.8	1.1	52.0	Downsize
27	150	Pump	72.8	93.6	86.4	6.8	9.2	Keep this motor
28	250	Scrubber	35.1	87.9	80.4	1.4	41.9	Downsize
29	250	Scrubber	67.4	95.8	91.5	59.1	-6.5	Keep this motor

Fig. 19. Results of field testing of industrial motors. The internal rate of return (IRR) is after taxes and corrected for inflation [12].

Efficient Motor Drive Systems and The Technology Menu
- E.D. Larson

Of all end-use devices, motors consume the largest total amount of electricity. Standard-efficiency and energy-efficient motors (EEMs) are discussed in the first volume of the Technology Menu for Efficient End-Use of Energy (see list of workshop resource materials). Motor manufacturers typically define EEMs as higher-efficiency, higher-cost units. Fig. 20 compares the efficiency and cost of some standard motors and EEMs. The efficiency advantage of the EEMs appears relatively small, but because the annual electricity cost to run a motor can easily be five times its initial capital cost, the extra cost of the EEM can often be recovered quickly, as illustrated by the high rates of return shown in Fig. 21 for a range of electricity prices and annual operating hours.

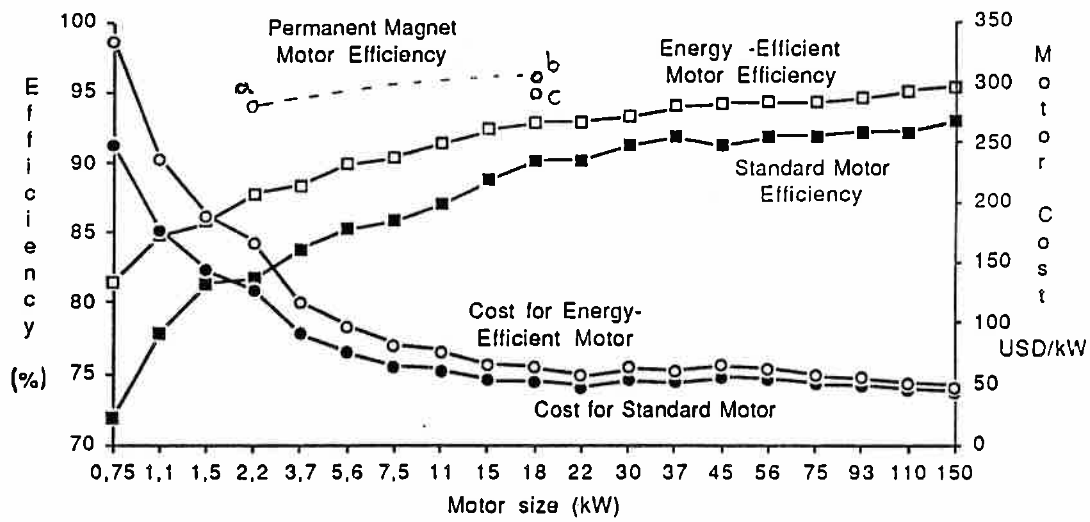


Fig. 20. Estimated full-load efficiencies and wholesale prices of standard and energy-efficient motors in Canada [14]. Also shown are measured efficiencies of Ferrite (a,b) and Rare-Earth Cobalt (c) permanent magnet motors. Note that the x-axis is not linear.

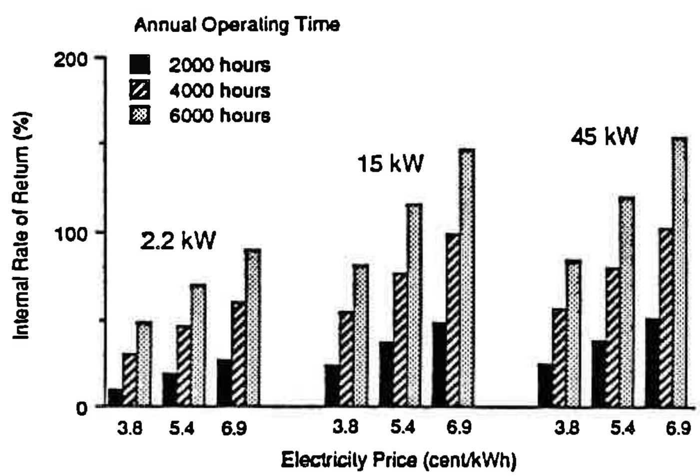


Fig. 21. Internal rates of return calculated for extra investments in energy efficient motors versus standard-efficiency motors [14]. Costs and efficiencies are from Fig. 20.

4.3. Electricity Use in Buildings

Residential Buildings

- S. Nadel

Electricity use in buildings accounts for approximately half of total Thai electricity use. Building electricity use is split evenly between the residential and the commercial sectors (Fig. 22).

The major residential uses of electricity in Thailand are lighting (which accounted for 46% of residential electricity use in 1986), refrigerators (24%), air-conditioning (6%) and other (25%). Electricity use per household is highest in Bangkok and other municipalities (1986 average of over 500 kWh/year) and lowest in rural areas (approximately 100 kWh/year in 1986) (Fig. 23). Residential electricity use is growing rapidly (15%/yr over the 1970-86 period) as (a) rural electrification efforts proceed, (b) urbanization proceeds, and (c) households increase appliance purchases, particularly appliances with high electricity use such as refrigerators and air-conditioners.

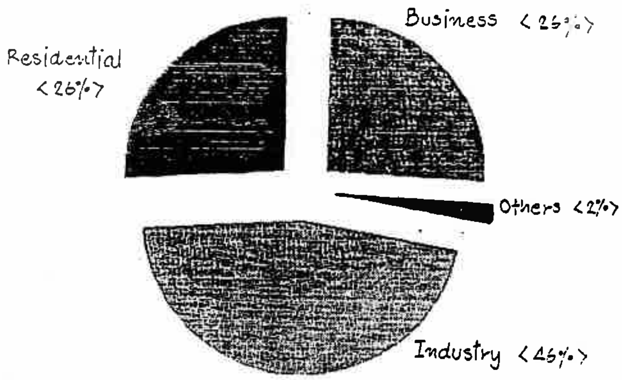


Fig. 22. Thai electricity consumption by sector in 1986 [2]. Total consumption was 22,034 GWh.

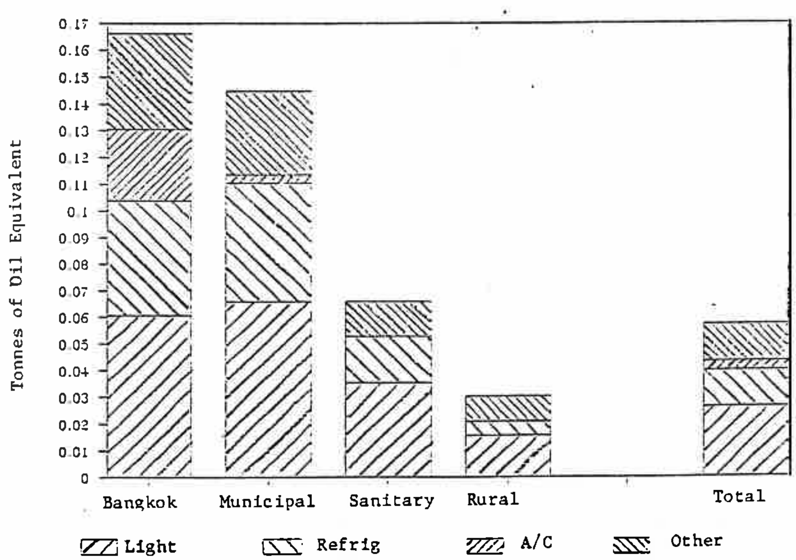


Fig. 23. Thai electricity use per household, by area and end-use. Source: S. Nadel lecture at the workshop.

Residential buildings are important targets for conservation and load management efforts because electricity use in the residential sector peaks in the evening, the same time that national electricity demand peaks (Fig. 24). Major conservation opportunities include improved efficiency in refrigerators, air-conditioners and lighting equipment. Much of this improved efficiency equipment is available in Thailand but is not purchased due to a lack of consumer information about this equipment and to higher initial costs. In some cases, high efficiency equipment produced elsewhere in the world is not available in Thailand. For example, the typical Thai refrigerator uses over 3 kWh/liter-year, the best models produced in Japan, Europe and the US use 0.8 to 1.6 kWh/liter-year (Fig. 25).

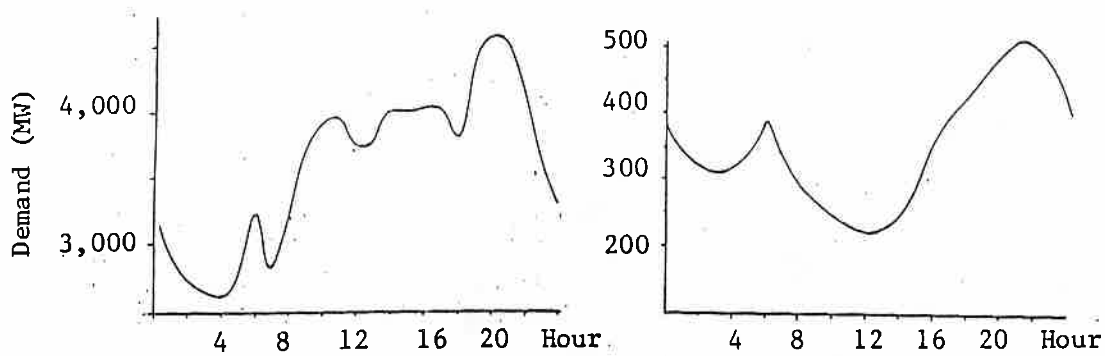


Fig. 24. The Electricity Generating Authority of Thailand's Monday-Saturday load profile (left) and the Metropolitan Electricity Authority's peak day residential demand profile (right). Source: S. Nadel lecture at the workshop.

Brand and location	Model	Capacity (liters)	Elect. use (kWh/yr)	Unit elect. use (kWh/l/yr)
Single door models				
Hitachi (Japan)	RX717	170	180	1.06
National (Japan)	NR214R	205	190	0.93
Gram (Europe)	K244	231	200	0.87
Electrolux (Europe)	RF930	245	220	0.90
AEG (Europe)	KS380	330	275	0.83
Bosch-Siemens (Europe)	KK3650	346	290	0.84
Gram (Europe)	K395	371	315	0.85
Two door models				
National (Japan)	NR305HVP	300	275	0.92
Mitsubishi (Japan)	MR3126	310	290	0.94
Toshiba (Japan)	GR415AS	410	430	1.05
National (Japan)	NR434TR	425	445	1.05
Electrolux (Europe)	TR1120C	315	475	1.51
Gram (Europe)	KF355	337	550	1.63
Whirlpool (U.S.)	ET17HKXR	485	750	1.55

Fig. 25. Some of the most energy-efficient refrigerators produced in the world. Electricity use in Europe, Japan, and the US are based on different standardized tests, so consumption values for different locations are not strictly comparable. Source: American Council for an Energy-Efficient Economy, Washington, DC.

Commercial Buildings

- M. Levine

Electricity use in commercial buildings accounts for about 1/4 of total electricity use in Thailand. The major commercial-sector uses of electricity are for air conditioning, lighting and ventilation (Fig. 26). Thai commercial buildings vary widely in their energy use. For example, a study of 26 Thai hotels, retail and office buildings found electricity use ranging from approximately 125 to 450 kWh/m^2-yr. Over the 1970-86 period, commercial building electricity use has grown 17%, representing one of the fastest growth rates in the world. This growth is primarily driven by the construction of many millions of square meters of new commercial buildings.

Many conservation opportunities are available in Thai commercial buildings including more efficient equipment (e.g. improved lamps, ballasts, fixtures, windows, HVAC equipment, distribution systems and controls) and improved design strategies. Two particularly promising design strategies in Thailand are use of overhangs (to block direct sunlight) and daylighting (using daylight to illuminate interior spaces, thereby cutting down on the amount of artificial illumination required). Combining these strategies can reduce electricity use in a typical office building by approximately 30% (Fig. 27).

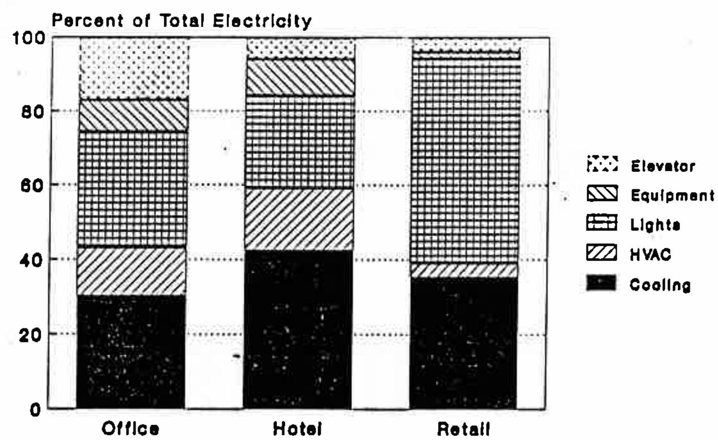


Fig. 26. End-uses of electricity in Thai building prototypes. Source: M. Levine lecture at the workshop.

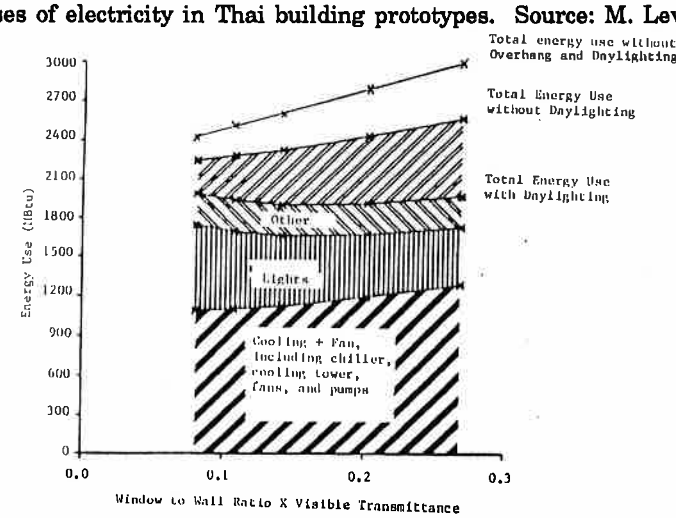


Fig. 27. Effect of daylighting and overhang on energy use in a building with a variable air volume system. Source: M. Levine lecture at the workshop.

4.4. Electricity Scenarios for India and Brazil

A Development-Focussed End-Use-Oriented Energy Perspective Plan for Karnataka State, India

- A.K.N. Reddy

Traditional supply-biased energy projections have largely ignored conservation, environmental impacts, and renewable fuels. Demand projections have been made on the basis of an assumed GDP elasticity of energy demand. For example, projections of developing-country electricity demand in 2000 made at the 14th World Energy Conference assumed GDP-elasticities from 1.3-1.5, yielding an annual electricity demand growth rate, 1980-2000, of 4.5% to 6.8% (see Table 1). World Bank calculations presented at the 14th World Energy Conference assumed a 6% electricity demand growth rate to calculate essentially unachievable future power sector investment requirements of $100 billion/year for developing countries. (This is based on a current demand of 600 GW and an assumed unit cost of new capacity of $2,777/kW.)

A similar calculation was done to develop the most recent official electricity plan for the State of Karnataka, India. A 9%/year electricity demand growth rate was assumed (Fig. 28), yielding a power sector investment need of some $1.2 billion/year to the year 2000. Despite these massive investments, the official electricity plan concludes gloomily that:

> ... Energy shortages will continue up to, and even in, 1999-2000 AD, *with little hope thereafter* (emphasis added).

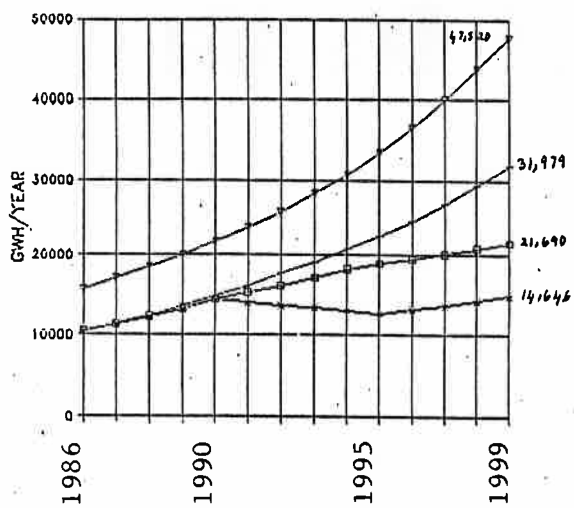


Fig. 28. Electricity scenarios for the state of Karnataka, India. The upper-most curve is the official government projection for generation requirements. The next line down is the official demand projection. The two lowest curves are alternative scenarios developed emphasizing energy efficiency. Source: A.K.N. Reddy lecture at the workshop.

An alternative electricity plan developed for Karnataka, using end-use-oriented analysis and considering energy as a means to an end rather than an end in itself, indicates that a much lower electricity demand growth rate--about 2.7%/year--can provide the same level of energy services as in the official plan, if energy efficiency is emphasized. Such a plan would also be less costly per kW, so that overall electricity-related investments would be much lower than in the official plan.

The alternative electricity plan was developed by disaggregating the electricity use by sector (Fig. 29) and analyzing in detail the growth in activity levels and the potential energy efficiency improvements that could be made in key end-uses in each sector. Detailed lifecycle cost calculations were also done to develop a least-cost ordering of conservation and new supply measures (Fig. 30), which in turn was used to develop an integrated energy services supply curve (Fig. 31).

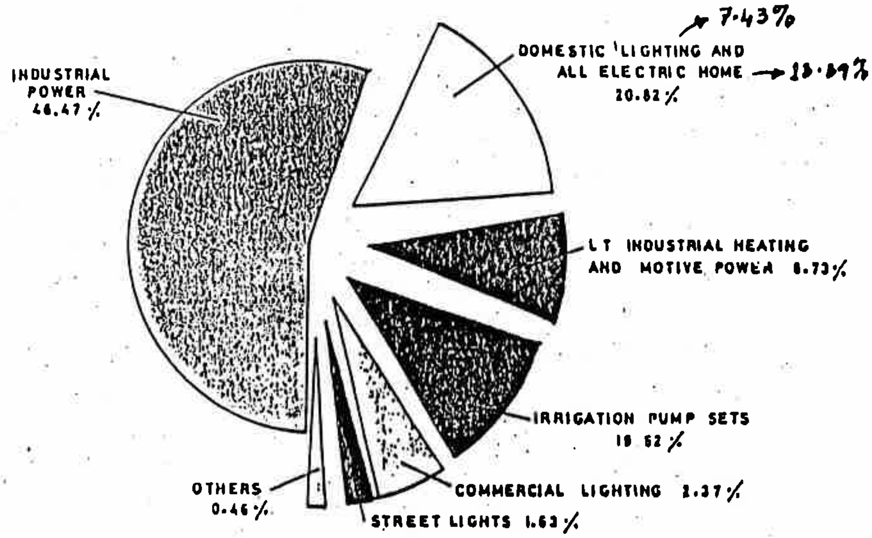


Fig. 29. Sales of electrical energy to various consumers in Karnataka, 1986-87. Total sales were 7768 GWh. Source: A.K.N. Reddy lecture at the workshop.

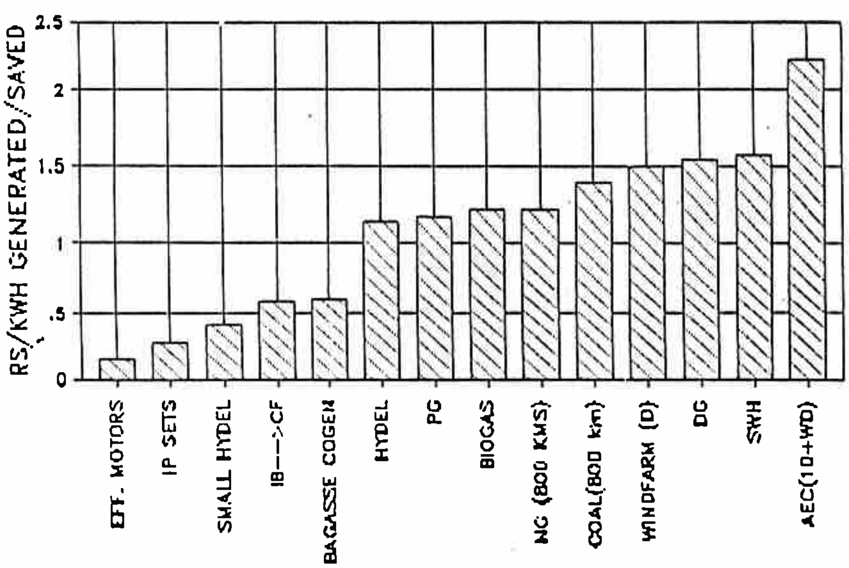


Fig. 30. Unit cost of electricity generated or saved developed for the state of Karnataka, India. Source: A.K.N. Reddy lecture at the workshop.

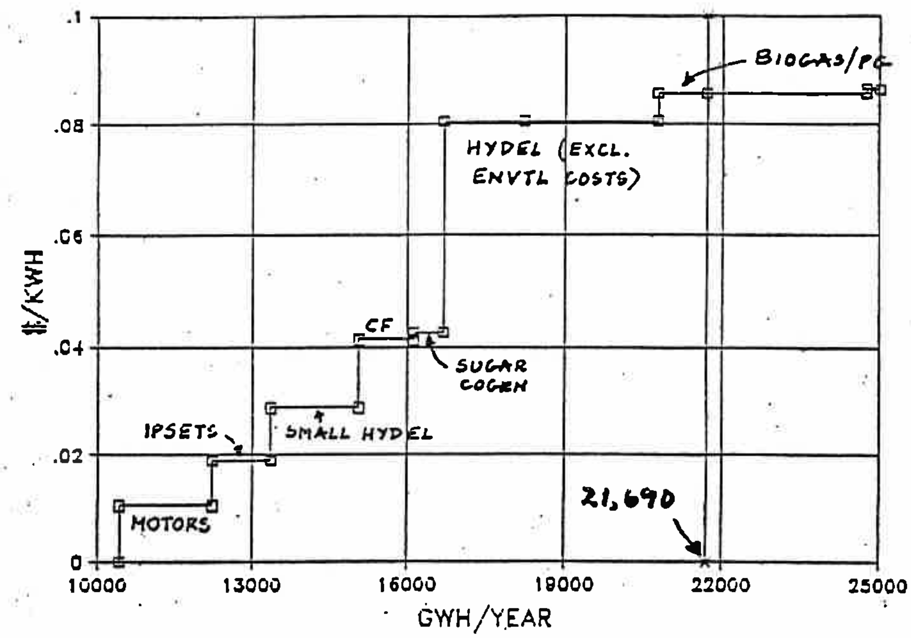


Fig. 31. Integrated cost-supply curve of energy services (conservation or new supply) for Karnataka. Source: A.K.N. Reddy lecture at the workshop.

New policies are required to implement development-focussed energy plans such as the alternative electricity plan for Karnataka because there are consumers who are: (1) ignorant of energy efficiency improvements, (2) knowledgeable about efficiency, but cannot afford front-end costs, and (3) indifferent because their energy costs are an insignificant part of their total costs. Market forces are an efficient allocator of money, materials, and manpower, but market limits are not necessarily good for safeguarding equity, environment, and the long term. Thus, new policy instruments need to be considered to implement alternative plans: information and consumer education, loans from utilities and recovery of loans through electric bills, electricity pricing based on long-run marginal costs, rationing, regulations/standards/labelling, measure-specific policy packages, and others.

Rural Electrification and Rural Energy Centers

- A.K.N. Reddy

Our experience in Pura village, India, indicates that the wide-scale establishment of decentralized rural energy centers (e.g., with biogas plants and/or wood gasifiers providing fuel for dual-fuel engine-generator sets) would result in an improvement in the quality of life for rural people, e.g. by providing piped drinking water, electric illumination, rural industries, etc. It would also lead to the generation of a great deal of rural employment and the strengthening of self-reliance of villages through their energization.

End-Use Electricity Strategies for Brazil

- J.R. Moreira

Electricity demand is growing rapidly in Brazil (Fig. 32). More efficient use of electricity is often cost effective, as shown in Fig. 33, which compares the unit capital cost of saving a kW of electricity through use of variable-speed motor drives against the capital cost of building new electric generating capacity to supply a kW. And there are major other opportunities to increase end-use efficiency cost-effectively. It is technically and economically feasible to reduce projected electricity consumption in 2000 by 20% through the purchase of more efficient motors, lighting equipment, appliances, and other end-use equipment. Savings estimates for six important end-uses are shown in Fig. 34. Many efficient end-use devices are already produced in Brazil, but largely for export. Adopting a variety of more efficient end-use equipment domestically could strengthen Brazil's economic growth and export potential.

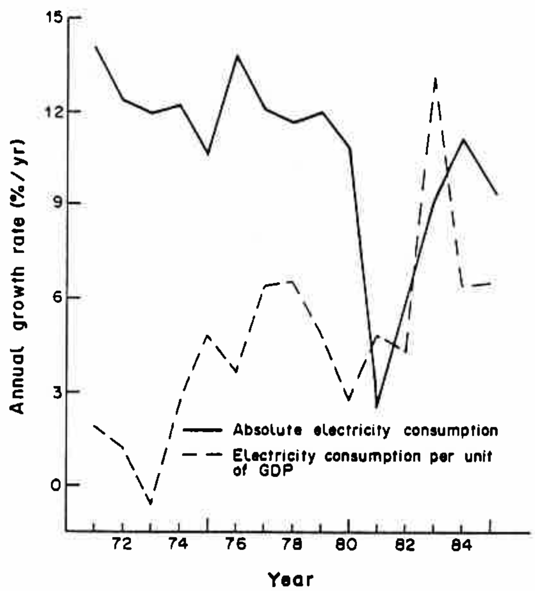


Fig. 32. Trends in electricity consumption in Brazil [13].

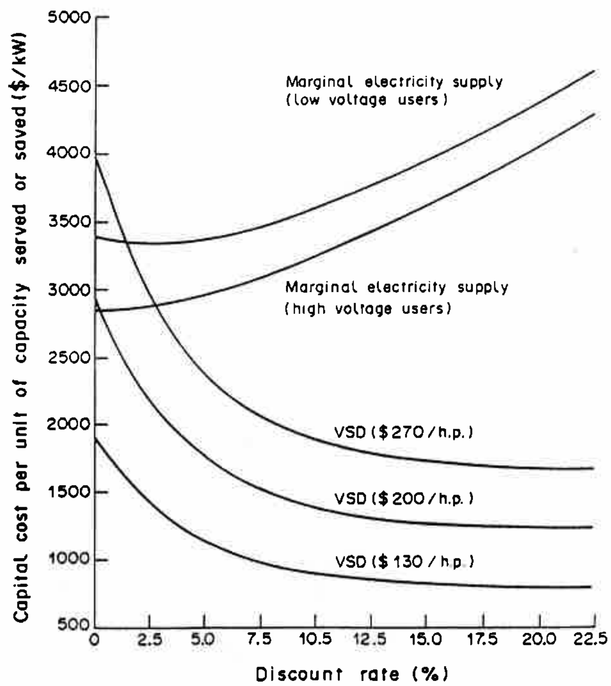


Fig. 33. Comparison of the capital cost for marginal electricity supply and demand reduction using variable speed drive (VSD) (assuming 20% electricity savings with a 100 h.p. VSD) [13].

A national electricity conservation program, PROCEL, was begun in 1985. It set a target of saving by 2000 about 41 TWh (Fig. 35), or about 1/2 of the potential savings identified in Fig. 34. While some progress is being made, low electricity prices, lack of information, a shortage of capital on the part of businesses and households, limited institutional support, and other barriers to implementation still exist.

4.5. Implementing Electricity Conservation

Energy Policy Issues and Efficiency Implementation Strategies
- S. Nadel and M. Levine

Energy efficiency strategies can help reduce the need for new (capital-intensive) power plants and the emissions of greenhouse gases--energy use and production accounts for over half of all greenhouse gas emissions--without affecting the goods and services that are produced. In addition, efficiency improvements can lower consumer electric bills and reduce the cost of production, thereby strengthening export potential.

End-use area	Current forecast (TWh)	Savings potential (%)	Savings potential (TWh)
Industrial motors	164.8	20	33.0
Domestic refrigerators	24.7	60	14.8
Domestic lighting	16.5	50	8.2
Commercial motors	28.0	20	5.6
Commercial lighting	25.0	60	15.0
Street lighting	16.8	40	6.7
TOTAL	275.8	--	83.3

Fig. 34. Electricity demand and conservation potential in the year 2000 in Brazil [13].

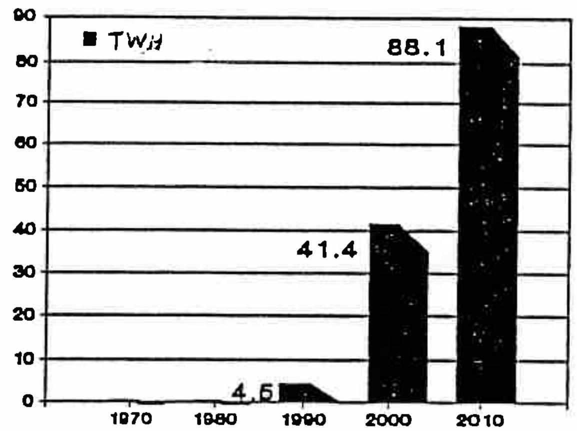


Fig. 35. Officially planned electricity saving targets for Brazil [12].

In order to promote energy efficiency, Thailand is beginning to pursue a number of strategies including time-of-use electric rates; industrial energy audits, loans and import-duty reductions; voluntary commercial building standards; and consumer information programs. A number of additional strategies have been successfully employed in other countries of the world and may be useful in Thailand. These include

- o appliance testing, labeling and minimum efficiency standards (presently employed in the U.S., Japan and Brazil).

- o mandatory commercial building codes (presently used in parts of Europe and North America and in Singapore).

- o utility incentive and direct installation programs (presently offered in parts of North America and being pilot-tested in Europe and Brazil).

- o expanded information programs, including demonstration programs and training programs for architects, engineers and facility managers (being pursued in many countries).

- o research and development of efficiency measures most appropriate for Thailand, including efforts to domestically produce appropriate products that are now only produced overseas (Japan illustrates the success of this strategy, and Brazil is actively working on this strategy as well).

Programs of these types can have dramatic impacts. For example, over the 1972-1993 period, energy use of the typical U.S. refrigerator is projected to decline nearly 60% as a result of electricity price increases, labeling and minimum efficiency standards (Fig. 36). Similarly, if Thailand's pending voluntary building standards for commercial buildings were made mandatory, savings in a typical office building would be approximately 25%. At a larger scale, development and implementation of full-scale utility conservation programs can likely reduce nationwide electricity use and demand by more than 10%. For example, New England Electric System, a major private electric utility in the United States, is implementing conservation and load management programs designed to reduce electricity generation needs by 1149 MW, corresponding to 14% of their projected generating requirements in 2008 or 31% of the projected new generating resources they expect to need between now and then (Fig. 37).

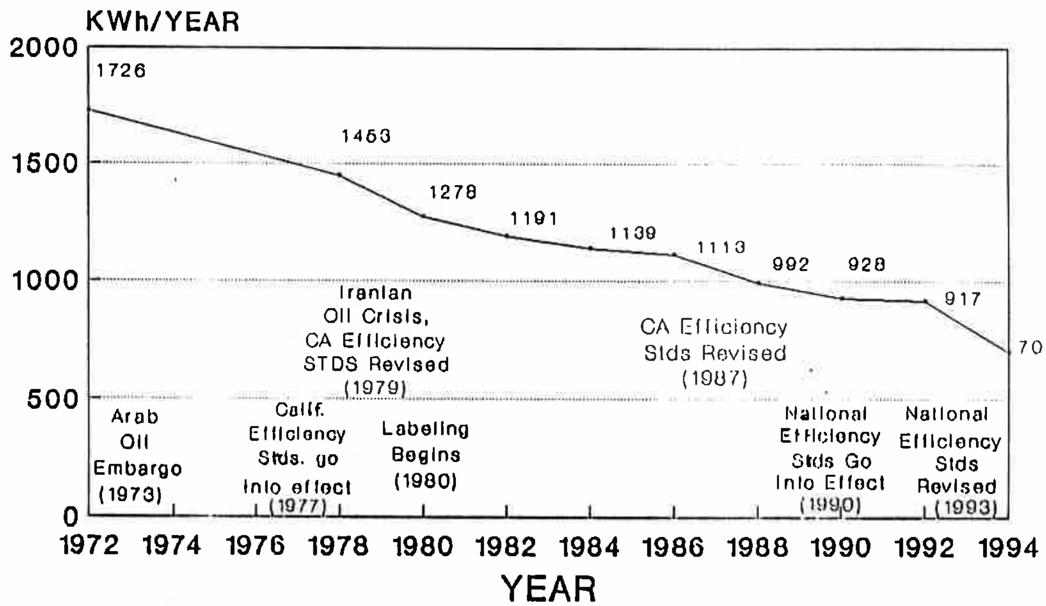


Fig. 36. Average electricity use of new refrigerators sold in the US. Source: Association of Home Appliance Manufacturer Historic Data, US Department of Energy projections.

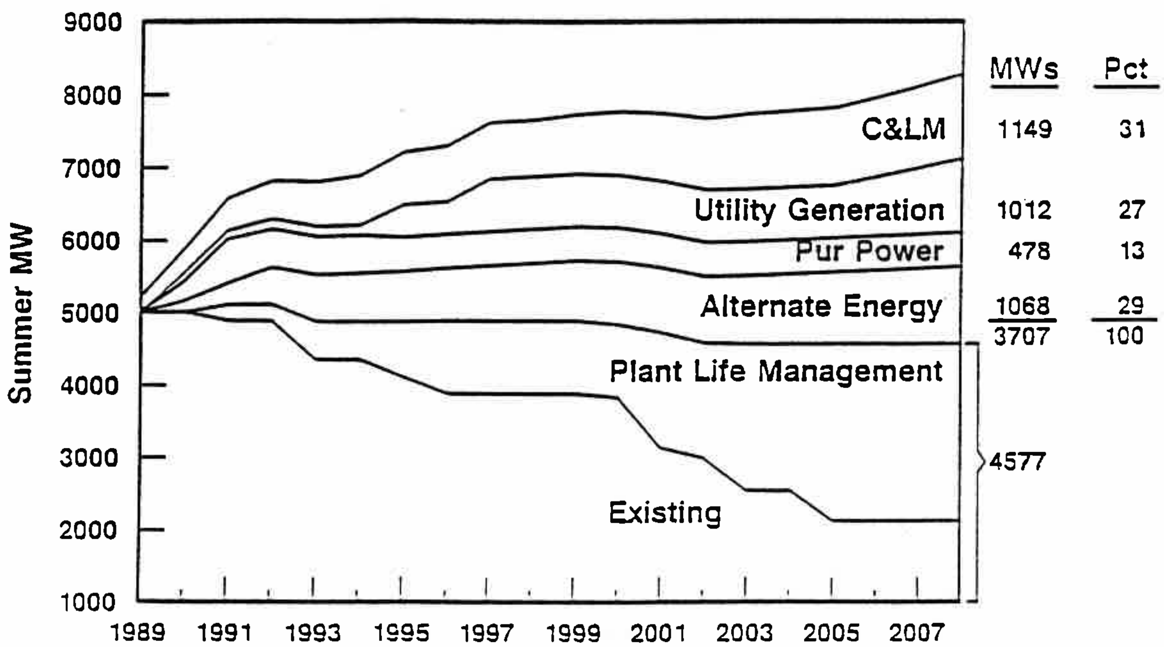


Fig. 37. Projected resource mix for the New England Electric System, including conservation and load management (C&LM). Source: S. Nadel lecture at the workshop.

4.6. Electricity Supply

Gas Turbines for Power Generation

- R.H. Williams

For the next two to four decades the gas turbine is likely to assume new roles in power generation worldwide--in central station and cogeneration applications. Recent and expected advances in gas turbine technology are making available small-scale units (< 100 MW_e) that are far more efficient than traditional steam-electric power plants. In a wide range of circumstances, gas turbine-based power plants will be able to provide electricity at lower cost and with less adverse environmental impact or safety problems than coal or nuclear steam-electric plants.

Already gas turbine/steam turbine combined cycles (Fig. 38) are attracting the interest of power planners throughout the world. While combined cycles offer many advantages compared to conventional steam-electric power plants, this class of energy-efficient gas turbine-based power systems does not exhaust the possibilities. Advanced gas turbine cycles involving steam-injection for power and efficiency augmentation (Fig. 38) have great promise for some important market applications. The various steam-injected gas turbine cycles that are available or under development (Fig. 39) are based on turbines derived directly from aircraft engines.

In developing countries, the relatively low unit capital costs (Fig. 40) of gas turbine power plants are attractive for helping to cope with the capital crisis in the power sector. Also, gas turbine capital costs are relatively insensitive to scale, making them attractive for use on small utility grids and in decentralized operations.

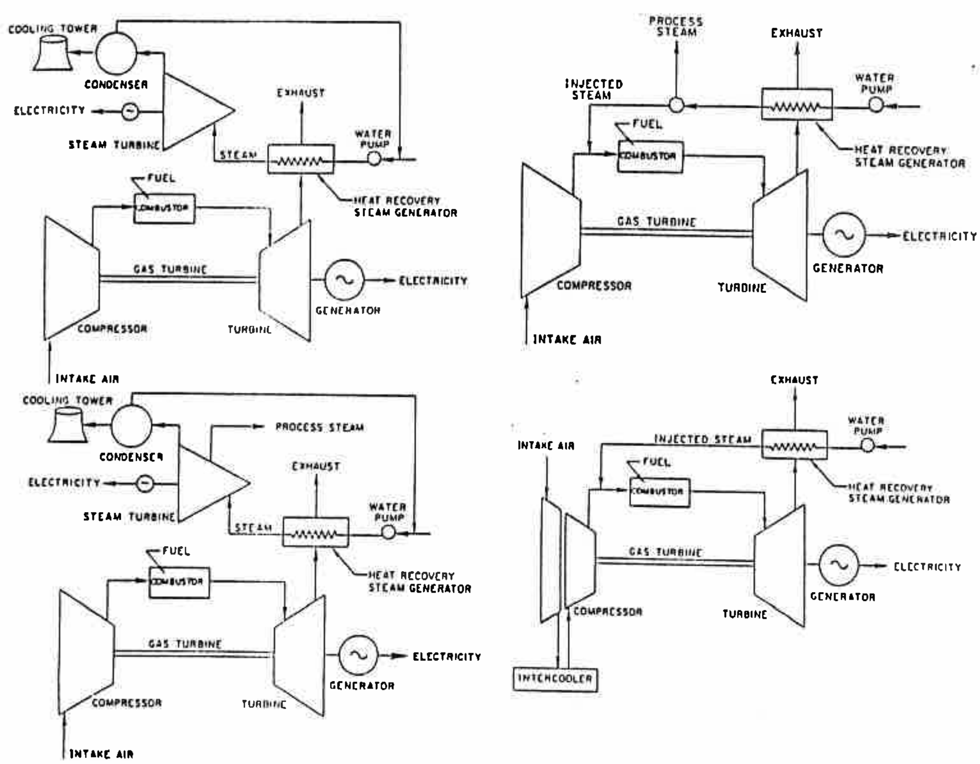


Fig. 38. Gas turbine cycle configurations: combined cycle for power (upper left), combined cycle for cogeneration (lower left), steam-injected gas turbine for cogeneration (upper right), and intercooled steam-injected gas turbine for power (lower right) [15].

	EFFICIENCY (%, HHV BASIS)	CAPACITY [MW(e)]	CAPITAL COST ($ PER kW)
STEAM-ELECTRIC (*)	36	2 x 500	750
COMBINED CYCLE (*)	45	400	500
VARIATIONS ON GE LM-5000/LM-8000:			
SIMPLE CYCLE (*)	33	33	
STIG (*)	40	50	600
ISTIG	47	114	~ 400
RH/ISTIG	50	195	
RH/ISTIG w/SR	54	160	~ 500

* COMMERCIALLY AVAILABLE

Fig. 39. Performance and cost characteristics of alternative natural gas-fired power generating technologies. Source: R.H. Williams lecture at the workshop.

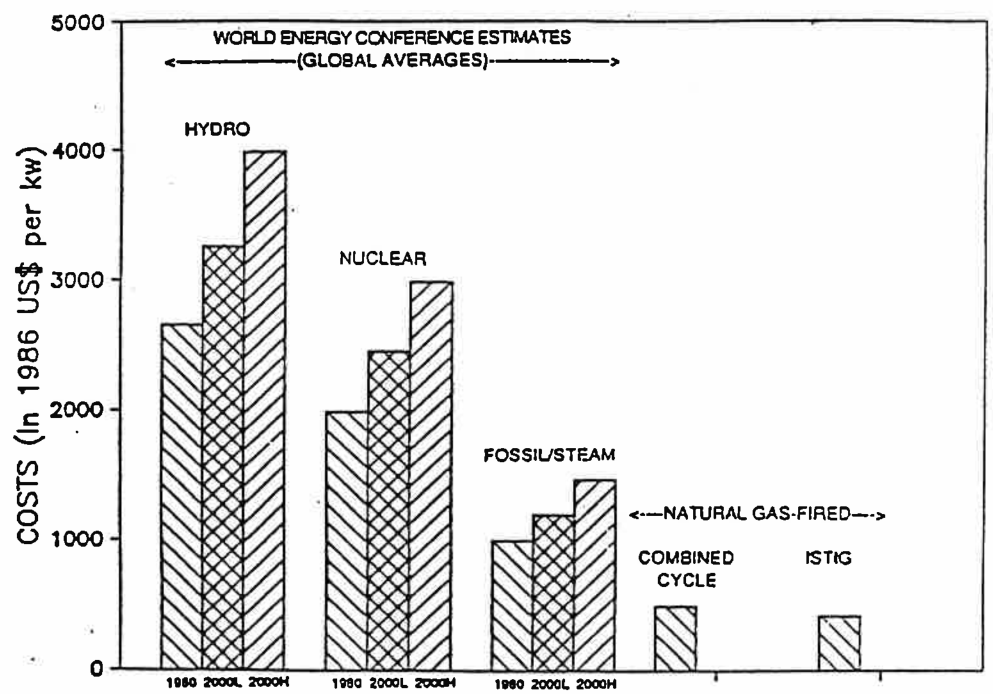


Fig. 40. Installed costs for new electrical generating equipment. 2000L and 2000H refer to low and high estimates of the World Energy Conference. ISTIG refers to the intercooled steam-injected gas turbine. Source: R.H. Williams lecture at the workshop.

Furthermore, with the aeroderivative gas turbines, a sophisticated on-site maintenance capability is not needed since major servicing would be done off-site (e.g. using the maintenance system set up for commercial-aircraft engines). And finally, there are large under-exploited natural gas resources in many developing countries. The initial use of gas for power generation in efficient gas turbines can provide the revenue stream needed to build distribution infrastructures that would permit gas to be used in other sectors as well.

Steam-injected gas turbines are also well suited for firing with gasified biomass, because biomass-based power systems must be relatively small (< 100 MW_e) to avoid the high costs of transporting biomass fuels long distances. Biomass can be grown renewably in many developing countries--in many cases more cheaply than imported oil. There is no net atmospheric carbon dioxide buildup if it is grown renewably, and bioenergy systems can help promote rural industrialization and rural employment generation. Biomass fired gas turbines are discussed further in the following two lectures.

The Ethanol Program in Brazil and Its Use as a Source of Electricity
- J.R. Moreira

Before the oil price shock of 1973, oil imports in Brazil required about 14% of foreign exchange earnings. By 1980, this had risen to nearly 50% and was contributing significantly to the increase in Brazil's foreign debt. Simultaneously, global demand for sugar was slowing (largely due to expanded use of artificial sweeteners), which impacted developing countries more seriously than industrialized countries (Fig. 41). These factors led to the development of the ethanol program, which today produces about 11 billion liters of fuel ethanol annually and accounts for as much of the country's automotive fuel supply as gasoline. Nearly 90% of new automobiles sold in Brazil operate on straight ethanol fuel (Fig. 42). The land area planted with sugarcane has nearly tripled since 1973, although it represents only about 1% of current land use in the country. In addition to the benefits of decreased reliance on imported oil, the use of alcohol can help reduce pollutant emissions from automobiles, and produces no net carbon dioxide. The importance of the latter consideration is evident when it is recognized that a significant fraction of CO_2 emissions in most countries comes from the transportation sector.

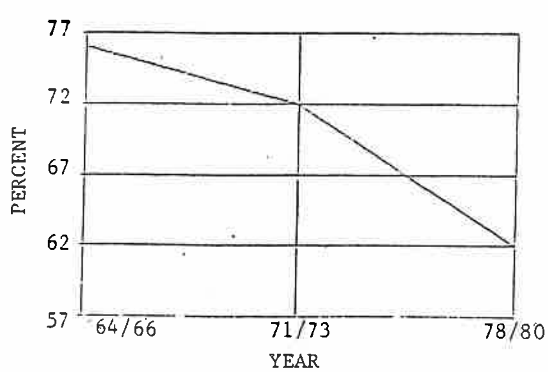


Fig. 41. Developing countries' share of total sugar exports over time [12].

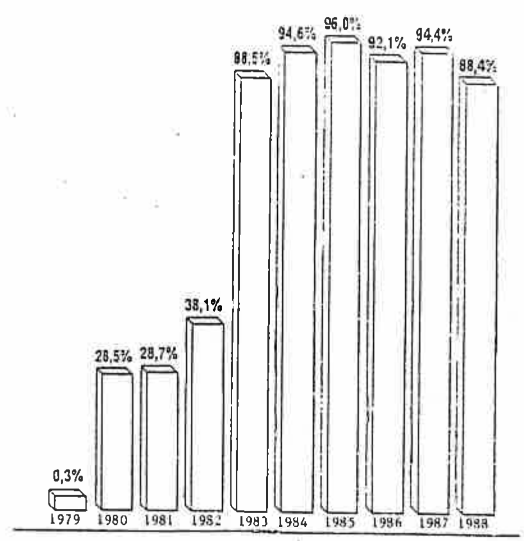


Fig. 42. Percent of all new cars sold in Brazil that are purely ethanol powered [12].

Alcohol production costs have been falling steadily in the 1980s (due largely to increased cane yields per hectare) (Fig. 43), but are still higher than today's wholesale gasoline price. While oil prices can be expected to rise in the future, the alcohol industry in Brazil could become more competitive by producing electricity as well as alcohol. The bagasse residues of cane crushing are presently used to fuel relatively inefficient steam-turbine cogeneration systems which meet only on-site needs for steam and electricity (Fig. 44). More efficient, higher-pressure steam turbine cogeneration systems could produce 6 or 7 times as much electricity, about 1/3 of which would be needed on-site (Fig. 44). The excess electricity could be sold to a utility, and recent legislation in Brazil requires the utility to pay a price for it equal to the cost the utility avoids by not having to generate the electricity themselves. The distiller can credit the additional revenue against the cost of alcohol production. Sales of excess electricity from alcohol distilleries have just recently started on a pilot basis in Brazil. As discussed in the next lecture, using advanced gas turbine technologies in the sugarcane processing industries would permit still larger amounts of electricity to be sold to the utility.

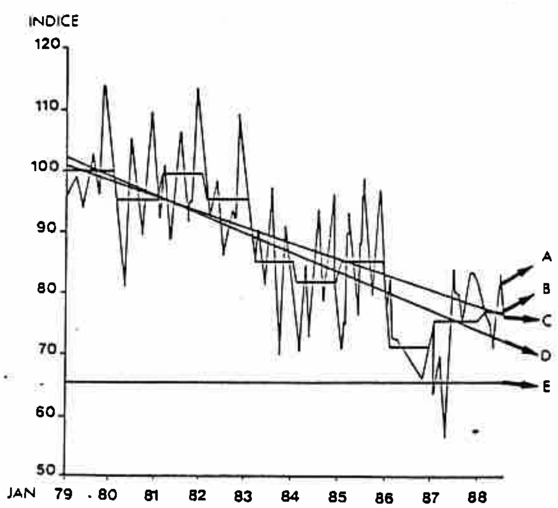


Fig. 43. Index of the inflation-corrected cost of anhydrous alcohol [16]. Lines A through D represent actual costs measured on different bases. Line E represents the optimized cost of production.

	PRESENT TECHNOLOGY	ADVANCED TECHNOLOGY
	STEAM TURBINE ($21\ kgf/cm^2$)	STEAM TURBINE ($42\ kgf/cm^2$)
STEAM (kg/1 ALCOHOL)		
PRODUCED	7.60	4.30
NEEDED	6.50	4.20
EXCESS	1.10	0.10
BAGASSE (10^3 t/ANO)		
PRODUCED	64.3	64.3
NEEDED	63.4	64.3
EXCESS	0.90	ZERO
ELECTRICITY		
PRODUCED	3.6	24.3
NEEDED	3.6	9.0
EXCESS	0.0	15.3

Fig. 44. Steam, bagasse, and electricity balances for an autonomous Brazilian alcohol distillery producing 120,000 liters per day and using present or advanced steam turbine cogeneration technology [12].

Biomass-Fueled Gas Turbine Cogeneration at Cane Sugar Factories: A Major Electricity Supply Option
- E.D. Larson

The world's cane sugar processing industries could support some 52,000 MW of electric power production capacity (the equivalent of 52 large nuclear power plants) based on biomass-gasifier steam-injected gas turbine (BIG/STIG) cogeneration capacity (Fig. 45). BIG/STIG units would permit sugar producers to generate 20 to 25 times the electricity needed on-site (Fig. 46), using as fuel during the milling season the bagasse from grinding the sugar cane and during the off-season the barbojo (tops and leaves which are currently burned on the field) (Fig. 47). Lower capital costs for biomass-fired gas turbine systems would make the excess electricity less costly than from steam-turbine systems and competitive in many cases with least-cost central station power (Fig. 48).

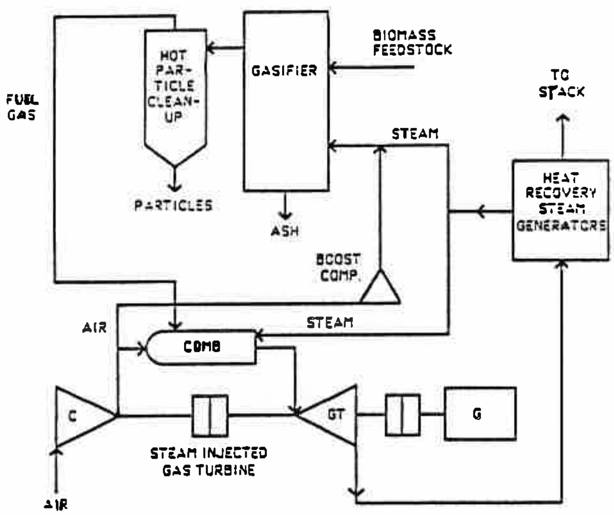


Fig. 45. Biomass-gasifier steam-injected gas turbine cycle [17].

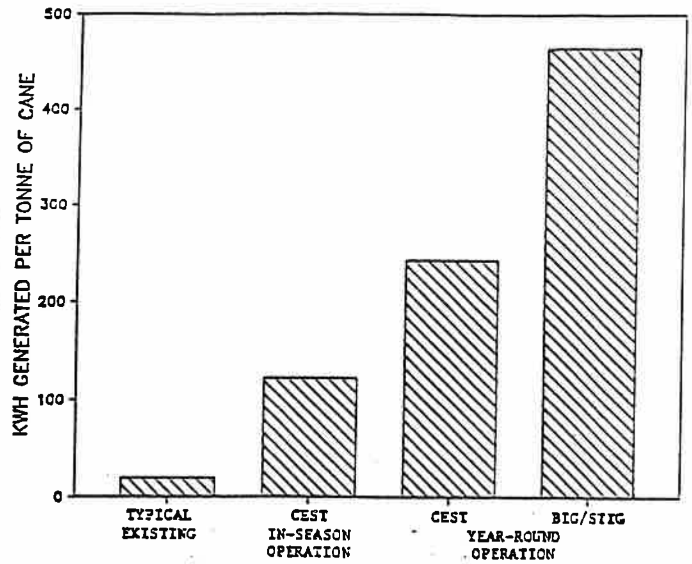


Fig. 46. Potential electricity generation with alternative cogeneration technologies at sugar factories. CEST refers to condensing extraction steam turbines and BIG/STIG refers to biomass-gasifier steam-injected gas turbines [18].

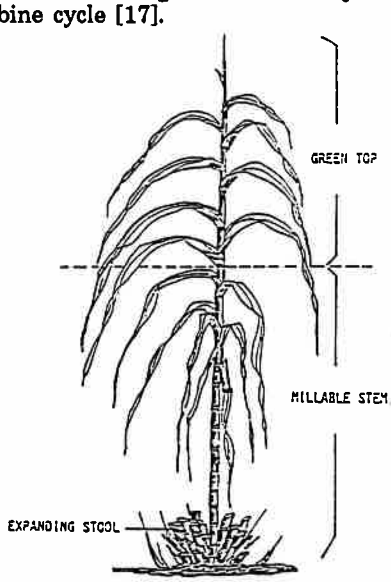


Fig. 47. A sugar cane plant.

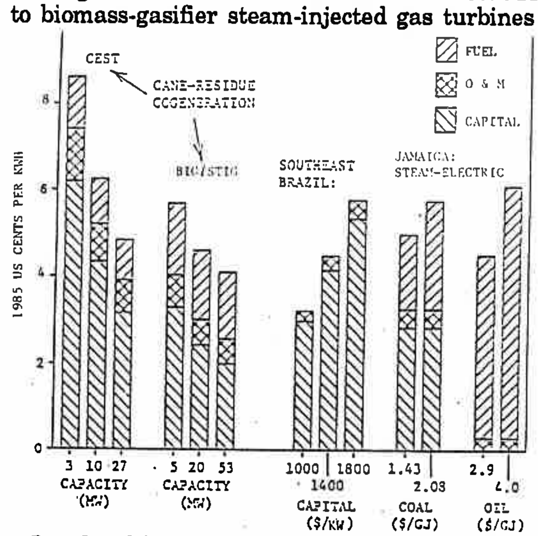


Fig. 48. Levelized busbar costs (assuming 12% discount rate) for cane-residue-fired cogeneration and for alternative central station power generation [18].

The potential electricity production from sugar cane using gas turbines in all developing countries is about 1/4 of the total utility electricity production there (Fig. 49). The electricity production would be greater still if there were an increase in the production of alcohol from cane. Alcohol distillers using an advanced BIG/STIG technology (BIG/ISTIG) could make electricity competitively with least-cost central station power plants, and alcohol that would compete with gasoline at today's relatively low oil price (Fig. 50).

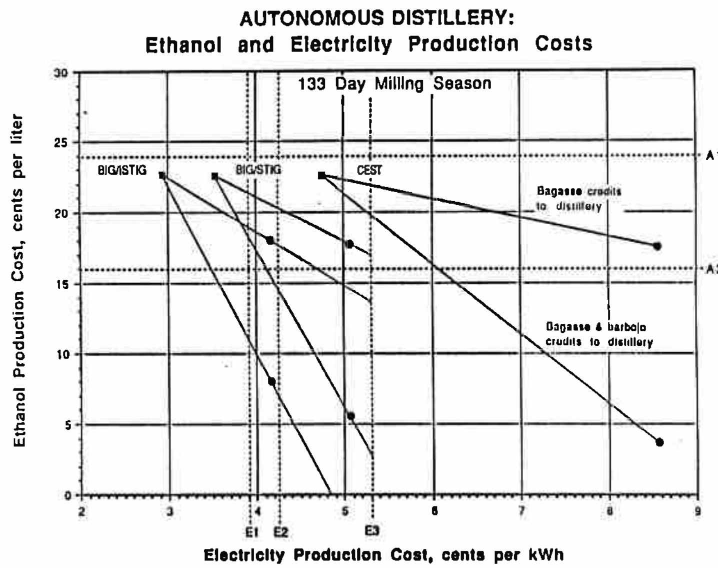


Fig. 49. Estimated ethanol and electricity production costs at an autonomous Brazilian distillery using alternative cogeneration technologies: steam turbines (CEST) and biomass-gasifier steam-injected gas turbines (BIG/STIG) and intercooled steam-injected gas turbines (BIG/ISTIG) [19]. The broken lines represent: A1, the price of ethanol which would make it competitive with gasoline as an octane-enhancing additive (at the 1988 world oil price); A2, the price of ethanol which would make it competitive as a neat fuel; E1, E2, and E3, central-station electricity production costs with oil-fired thermal plant (operating cost only), new Brazilian hydro-electric, and new coal-fired thermal plant.

	A	B		A	B	A	B
TOTAL DEVELOPING COUNTRIES						304	1124
ASIA						89	559
India	31.6	129.5	Iran	0.90	17.5		
China	19.0	327.7	Vietnam	0.81	1.69		
Thailand	10.8	16.2	Burma	0.45	1.52		
Indonesia	7.6	11.9	Bangladesh	0.42	2.95		
Philippines	7.4	17.4	Malaysia	0.32	11.1		
Pakistan	6.4	14.9	Nepal	0.12	0.234		
Taiwan	3.4	45.0	Sri Lanka	0.07	2.07		
CENTRAL AMERICA						65	100
Cuba	35.5	10.3	Jamaica	0.94	1.30		
Mexico	15.7	73.2	Panama	0.72	2.71		
Dominican Rep.	4.2	2.33	Belize	0.49	0.055		
Guatemala	2.3	1.42	Barbados	0.45	0.339		
El Salvador	1.2	1.45	Trin./Tob.	0.36	2.30		
Nicaragua	1.1	0.945	Haiti	0.23	0.352		
Honduras	1.0	1.04	St. Chris.	0.12	na		
Costa Rica	1.0	2.42					
SOUTH AMERICA						116	257
Brazil	95.0	143.6	Guyana	1.1	0.255		
Colombia	6.1	21.3	Bolivia	0.78	1.40		
Argentina	5.5	36.2	Paraguay	0.36	0.569		
Peru	3.3	7.25	Uruguay	0.23	3.47		
Venezuela	2.1	39.0	Suriname	0.05	0.175		
Ecuador	1.3	3.09					
AFRICA						32	167
South Africa	11.4	109.0	Mozambique	0.26	3.25		
Egypt	3.7	17.2	Somalia	0.24	0.073		
Mauritius	3.1	0.320	Nigeria	0.23	7.45		
Zimbabwe	2.1	4.16	Angola	0.23	1.46		
Sudan	2.0	0.910	Uganda	0.15	0.569		
Swaziland	1.8	0.075	Congo	0.11	0.195		
Kenya	1.6	1.73	Mali	0.09	0.080		
Ethiopia	0.87	0.618	Gabon	0.05	0.530		
Malawi	0.69	0.410	Burk. Faso	0.05	0.123		
Zambia	0.64	10.3	Chad	0.04	0.065		
Ivory Coast	0.57	1.94	Guinea	0.02	0.143		
Tanzania	0.47	0.720	Sierra L.	0.02	0.136		
Madagascar	0.45	0.342	Benin	0.02	0.016		
Cameroon	0.32	2.15	Liberia	0.01	0.359		
Zaire	0.30	1.48	Rwanda	0.01	0.066		
Senegal	0.30	0.631					
OCEANIA						2	1
Fiji	1.6	0.241	Papua N.G.	0.13	0.441		

Fig. 50. Gas turbine electricity generating potential from sugar cane based on the 1985 cane production level, (A), and the actual total electric utility generation in 1982, (B), in developing countries (in 10^9 kWh per year) [18].

5. FINAL PRESENTATIONS BY PARTICIPANTS

Working in teams the participants prepared analyses which they presented on the second to last day of the workshop. The analyses focussed on one or more of the topics of the workshop afternoon exercises and built on spreadsheets used in those exercises. Because of time constraints, most teams had less than one full day to prepare their presentations, and the results can be considered preliminary. The presentations were all of remarkably high quality, given the short preparation time and the little previous background most participants had in end-use analysis. The presentations are summarized here:

Residential Sector Energy Demand in Thailand

The team of Surapol, Thumrongrut, Prayode, and Kawee presented an end-use analysis of electricity demand in the residential sector, with particular emphasis on the effect of income distribution and urban/rural population distribution. The demographic analysis was combined with appliance-specific end-use efficiency improvement assessments to create a total of five scenarios of future residential sector electricity demand. Increased urbanization between 1988 and 2001 was found to have relatively little effect on electricity demand. In contrast, increases in the fractions of medium and high income earners would lead to large increases in demand.

Energy Demand Projection for the Thai Industrial Sector

The team of Suwit and Warunee presented an analysis of energy use in the industrial sector. They projected value-added by sub-sector and made estimates of possible future savings in electricity and fuel to develop a scenario for total industrial sector energy demand in 2010. The rate of growth of industrial electricity demand implied in their scenario was some 2/3 of that forecast by the government for the period to 2001. The estimated total cost of the assumed electricity conservation measures was about US$0.02 per kWh saved.

A Thai Industrial Energy Analysis: Rubber Industry

Suteera presented a technical and detailed economic end-use analysis of replacing natural draft ventilation with forced-draft ventilation in curing houses of Thailand's rubber industry. Forced-draft curing would increase the industry's productivity and reduce the wood burned (per unit of production) to provide the heat for curing. Overall unit production costs would also decrease.

Commercial Buildings in Thailand

The team of Tirachoon, Thira, and Pongsiri developed a scenario of future end-use electricity demand in commercial buildings. Their presentation addressed the impact of electricity prices, expected growth in commercial floor space, and penetration rates of energy efficient technologies. Their scenario, which was broken down in terms of demand by building type and end-use technology, indicated a doubling of commercial sector electricity demand in 2001 compared to the 1988 level. The increase in demand would be about 60% of that given in the official government forecast. They estimated the cost of conserved electricity to range from a low of 0.37 Baht/kWh saved for lighting improvements to 0.7 Baht/kWh saved for improvements in air conditioning efficiency.

Electricity Supply Cost Analysis for Thailand

The team of Supawadee, Mayurapan, and Pongtorn presented a cost analysis of four central station electricity generating options in Thailand: coal-fired steam plant, hydro-electric, advanced natural gas-fired intercooled steam-injected gas turbine (ISTIG), and biomass-fired dendrothermal plants. For each technology, the team showed graphs of the levelized busbar costs of electricity and the annual revenue required over an assumed 30-year plant life to meet production costs. A somewhat surprising result was that a dendrothermal plant using plantation-grown eucalyptus (a scheme being studied by the National Energy Administration) would produce less costly electricity than either coal or hydro plants in Thailand.

6. FOLLOW-ON ACTIVITIES

Part of the final day of the workshop was spent discussing possible activities that the participants could carry on after the workshop. A first, tangible step was taken by the participants toward continuing work in end-use analysis when they created a formal organization through which to maintain interaction with each other. Several ideas were considered for naming the group--"Energy Conservation Working Group (ECWG)," "Thai Energy Association (TEA)," "Thai Energy Efficient Group (TEEG)," and "Thai Council for an Energy Efficient Economy (TCEEE)." No final decision was made regarding the name. Miss Warunee Tia, one of the participants, offered to act to coordinate the group's activities. Reference materials from the workshop were placed in her care at King Mongut's Institute of Technology Thonburi. Mark Cherniack, the Director of the Asia Office of the International Institute for Energy Conservation (Bangkok), offered to act as a liason between the group and the instructors. Both the participants and instructors expressed a mutual interest in maintaining contact.

A number of possible follow-on activities were discussed that could be undertaken by participants individually or collaboratively:

- Prepare technical journal articles and popular, policy-oriented articles (e.g. newspaper op-eds) on end-use-oriented energy scenarios for Thailand based on extension and refinement of the analysis initiated at the workshop.
- Continue to develop and refine the data base for Thai end-use analysis, e.g., define key data needs, verify savings from previous energy audit/retrofits, compile data bases (e.g. on measured savings, energy-efficient technologies, national end-use survey data, etc.).
- Translate ***Energy for Development*** [9] into Thai.
- Begin a newsletter on energy efficiency.
- Develop scenario analysis projects jointly with the Load Forecasting Working Group.
- Support university students in end-use research projects.
- For university professors, develop course curricula for teaching end-use energy analysis.

- Coordinate all efforts with other individuals and groups involved with energy conservation in Thailand.

7. WORKSHOP EVALUATION

There was a strong concensus among both participants and instructors that the workshop was highly successful. The high level of interest from participants was reflected in part by lively discussions with instructors, by full daily attendence, by the extra hours spent working before and after the scheduled sessions, by the consciencious efforts to prepare final presentations, by the high quality of those presentations, by the enthusiasm generated for undertaking follow-on activities (see above), and by responses received on a 10-question evaluation form distributed to participants on the second to last day of the workshop. Of the 18 participants that completed the workshop, 12 completed the evaluation form. Their responses are summarized here:

1. Was this workshop the first opportunity you had to learn about energy conservation issues?

For all but two of the respondents this was their first exposure to energy conservation and/or end-use modeling issues.

2. Was the 10-day length of the seminar too long, too short, or just right for you?

Nine of the respondents felt the seminar length was just right. The remaining ones felt it was too short for the amount of material covered. Nobody complained about it being too long.

3. Was the time given for explaining the use of the spreadsheet program, Lotus 1-2-3, adequate?

Most of the respondents were satisfied with the amount of time allotted to learning about Lotus. One suggested that it would have been more effective for the instructors to use a computer at the front of the class, with "on-line" projection onto a screen for all participants to see easily.

4. Would you like to have received any of the materials before the seminar began? If so, which materials?

Nearly everyone said that some additional materials should have been distributed beforehand. Several participants suggested that the a detailed seminar schedule listing topics and objectives should have been given out ahead of time. One person suggested distributing ***Energy for a Sustainable World*** before the seminar so they could familiarized themselves with the concepts. Another felt it better for all of the materials to be distributed on the first day. Several of the participants expressed particular interest in receiving the materials on economics ahead of time.

5. What part of the seminar interested you the most? What part interested you the least?

The majority of respondents felt all topics were interesting. Special mentions were received on the economic analysis, commercial and industrial sectors. One person listed exposure to internationally-known experts as important.

6. Were there parts of the seminar that you would have liked more time spent on? Similarly, were there things we should have spent less time on or even skipped altogether?

Several people suggested that more emphasis be given to model development. That is, instead of presenting nearly complete models to work with and modify, starting from scratch and going through the model-building process. One mentioned that more time should be spent on interpretation of model results. Other suggestions focussed on particular topics covered in the seminar, probably reflecting the personal interests of each individual, with each major topic receiving a "vote". Some suggested allowing more time to prepare for the presentations given by participants at the end of the workshop. Only a few participants suggested limiting time on any of the topics.

7. Do you have any suggestions for the instructors about their audio-visual materials, handouts, or their presentations in general?

Most of the respondents were satisfied with the quality of the presentations and materials. A few complained about unreadable overheads and handouts that were late or confusing because they were many and unbound. One suggested having a Thai translator available to clarify confusing points.

8. If there was another workshop in Thailand in the future, what topic(s) would most interest you?

Half of the respondents expressed interest in a follow-up workshop focused on some aspect of industrial sector energy use. The use of case studies was mentioned several times. Again, economic analysis came up as a suggested topic for several people. Other suggestions were transportation, residential and commercial buildings, more complex models including those linking supply and demand sides, implementation, and more on energy and environment.

9. How are you planning to use what you have learned in the workshop in your future work?

Half of the respondents (presumably the professors in the group, who made up half of the workshop participants) plan to incorporate the course concepts into new or existing courses they are teaching. Some plan to apply the course to their research and several mentioned publishing the work. Others plan to enhance the spreadsheet models for use by their staffs in their respective agencies.

10. What kind of interaction (if any) would you like to have with the instructors in the future?

Most respondents desired general information exchange and being kept abreast of new developments in the instructors' respective fields. One wanted to have future visits to his institution and another the chance to collaborate to "achieve a goal of implementation on energy conservation in Thailand."

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Appendix A

THAI PARTICIPANTS

Mr. Arnupap Guptabutra
Head of Special Technology Section
Electricity Generating Authority
of Thailand
Jaransanitwong Road
Bang Kruai, Nonthaburi 11000
Phone: (2) 436-2714
Fax: (2) 436-2737

Mr. Chaiya Chamchoy
Deputy Director for Administrative Affairs
Energy Research and Training Center
Chulalongkorn University
Bangkok 10330
Phone: (2) 250-1313
Fax: (2) 254-7579

Mr. Kawee Jongkongkawutthi
Policy and Planning Analyst
National Energy Policy Office
Secretariat of the Prime Minister
Government House
Bangkok 10300
Phone: (2) 292-9029

Mr. Mayurapan Kasemsap
Nuclear Engineer
Energy Research and Development Division
National Energy Administration
Rama I Rd., Kasatsuk Bridge
Bangkok 10330
Phone: (2) 221-1877, 221-1853

Mr. Pongsiri Sirimongkol
Electrical Engineer
The Energy Conservation Center
of Thailand
17 Rama I Road
Patumwan, Bangkok 10330
Phone: (2) 223-4050-1, 223-0735

Dr. Pongtron Charunyakorn
Assistant Professor
Faculty of Engineering
Chulalongkorn University
Bangkok 10330
Phone: (2) 252-5001 ext. 310
Fax: (2) 252-1513

Mr. Prayode Jitrboon
Efficiency Engineer
Electricity Generating Authority
of Thailand
Jaransanitwong Road
Bang Kruai, Nonthaburi 11000
Phone: (2) 436-2720

Miss Somchit Suwanawong
Computer Engineer
The Energy Conservation Center
of Thailand
17 Rama I Road
Patumwan, Bangkok 10330
Phone: (2) 223-0735, 223-4050-1
Fax: (2) 225-6462

Mr. Suchat Nantawitaya
Energy Engineer
The Siam Cement Co., Ltd.
The Siam Cement Road
Bangsue, Bangkok 10800
Phone: (2) 586-3096

Mrs. Supawadee Swatdiponphallop
Associate Professor
Department of Electrical Engineering
Khon Kaen University
Khon Kaen
Phone: (43) 241-333 ext. 1157

Dr. Surapol Dumronggittigule
Lecturer and Deputy Dean for
Academic Affairs
Faculty of Engineering
Chiangmai University
Chiangmai 50002
Phone: (53) 221-699 (4140)
Fax: (53) 217 287

Dr. Suteera Prasertsan
Assistant Professor
Dept. of Mechanical Engineering
Prince of Songkla University
Hatyai 90110
Phone: (74) 235-800-9 ext. 2215-6
Fax: (74) 231-616

Mr. Suwit Smansotivong
Assistant Manager
Strategic Planning Division
Provincial Electricity Authority
200 Ngam Wong Wang Road
Bangkok 10900
Phone: (2) 589-0100 ext. 376

Mr. Thira Manussadhama
Engineer
Energy Economics Division
National Energy Administration
17 Rama I Road
Bangkok 10330
Phone: (2) 222-4102-10 ext. 275

Dr. Thumrongrut Mungcharoen
Lecturer
Department of Mechanical Engineering
Kasetsart University
Bangkaen, Bangkok 10900
Phone: (2) 579-4576 (office)
(2) 457-3620 (home)

Dr. Tirachoon Muangnapoh
University Professor
King Mongkut's Institute
of Technology North Bangkok
Piboonsongkram Road, Nagsue, Dusit
Bangkok 10800
Phone: (2) 585-8541-8 ext. 321
587-0026

Mrs. Wanit Apichatagon
Thailand Development Research Institute
Rajapark Building, 163 Asoke Road
Bangkok 10110
Phone: (2) 258-9012/17
258-9027/29

Miss Warunee Tia
Assistant Professor
School of Energy and Materials
King Mongkut Institute
of Technology Thonburi
Prachautit Road, Bangmod Rasburana
Bangkok 10140
Phone: (2) 427-0162

Mr. Wilas Rasdjarmrearnsook
Electrical Engineer
Engineering Service Department
The Energy Conservation Center
of Thailand
17 Rama I Road
Patumwan, Bangkok 10330
Phone: (2) 223-0735, 223-4050-1
Fax: (2) 225-646

Appendix B

INSTRUCTORS

John Busch
Research Assistant
Lawrence Berkeley Laboratory
University of California
3125 Building 90
Berkeley, CA
94720 USA
Phone: (415) 486-7279
Fax: (415) 486-5172

Thomas B. Johansson
Professor and Research Head
Department of Environmental and Energy Systems Studies
Lund University
Gerdagatan 13
S-223 62 Lund, Sweden
Phone: (46) 108639
Fax: (46) 108644

Eric D. Larson
Research Engineer
Center for Energy and Environmental Studies
Engineering Quadrangle
Princeton University
Princeton, NJ, 08540 USA
Phone: (609) 258-4966
Fax: (609) 258-3661

Mark Levine
Program Leader
Lawrence Berkeley Laboratory
University of California
3125 Building 90
Berkeley, CA
94720 USA
Phone: (415) 486-5238
Fax: (415) 486-5172

Evan Mills
Visiting Researcher
Department of Environmental and Energy Systems Studies
Lund University
Gerdagatan 13
S-223 62 Lund, Sweden
Phone: (46) 108645
Fax: (46) 108644

Jose Roberto Moreira
Profesor and Director of Energy Area
Institute of Electrotechnology and Energy
University of Sao Paulo
Sao Paulo, Brazil
Phone: (11) 815-2423
Fax: (11) 815-4272

Steven Nadel
American Council for an Energy-Efficient Economy
1001 Connecticut Ave. NW
Suite 535
Washington, DC,
20036 USA
Phone: (202) 429-8873
Fax: (202) 429-2248

Lars J. Nilsson
Research Assistant
Department of Environmental and Energy Systems Studies
Lund University
Gerdagatan 13
S-223 62 Lund, Sweden
Phone: (46) 109542
Fax: (46) 108644

Amulya Reddy
Professor and Chairman
Department of Management Studies
Indian Institute of Science
Bangalore -- 560012, India
Phone: (812) 364411 ext. 378
Fax: (812) 341683

Robert H. Williams
Senior Research Scientist
Center for Energy and Environmental Studies
Engineering Quadrangle
Princeton University
Princeton, NJ, 08540 USA
Phone: (609) 258-5448
Fax: (609) 258-3661

Appendix C

THE WORKSHOP PROGRAM

DAY 1: INTRODUCTION/OVERVIEW

Morning: Welcome and introductory comments
- Professor Woraphat Arthayukti, Energy Research and Training Center, Chulalongkorn University, Bangkok
- Pinij Gritiyaransan, Director, Energy Conservation Center of Thailand, Bangkok
- Dr. Charuay Boonyubol, Director, Energy Research and Training Center, Chulalongkorn University, Bangkok
- Mark Cherniack, Director, Asia Office, International Institute for Energy Conservation

Overview of End-Use Energy Analysis
- T.B. Johansson

Afternoon: *Introduction to Spreadsheet Analysis*
- E. Mills

DAY 2: END-USE SCENARIOS/ECONOMICS OF CONSERVATION

Morning: *End-Use Methodologies and Scenario Building*
- T.B. Johansson, E. Mills

Afternoon: *Economics of Electricity Conservation*
- E. Larson

DAY 3: INDUSTRIAL ENERGY USE

Morning: *Promoting Technological Innovation in the Basic Materials Processing Industries in Developing Countries as a Strategy for Quickening the Pace of Economic Development and Improving Industrial Energy Efficiency*
- R.H. Williams

Energy and Industry
- J.R. Moreira

Efficient Motor Drive Systems and the Technology Menu
- E. Larson

Afternoon: *An Industrial Sector Spreadsheet Model*
- L. Nilsson

DAY 4: ELECTRICITY SCENARIOS, INDIA

Morning: *A Development-Focussed End-Use-Oriented Energy Perspective Plan for Karnataka*
- A.K.N. Reddy

Rural Electrification and Rural Energy Centers
- A.K.N. Reddy

Afternoon: *Karnataka End-Use Scenario Spreadsheet Modified for Thailand*
- A.K.N. Reddy

DAY 5: ELECTRICITY SCENARIOS, BRAZIL

Morning: *End-Use Electricity Strategies for Brazil*
- J.R. Moriera

Afternoon: *Residential-sector spreadsheet scenarios*
- E. Mills

DAY 6: ELECTRICITY SUPPLY

Morning: *Gas Turbines for Power Generation*
- R.H. Williams

The Ethanol Program in Brazil and Its Use as a Source of Electricity
- J.R. Moreira

Biomass-Fueled Gas Turbine Cogeneration at Cane Sugar Factories: A Major Electricity Supply Option
- E.D. Larson

Afternoon: *Electricity Supply Cost Analysis*
- R. Williams, E. Larson

DAY 7: ELECTRICITY USE IN BUILDINGS

Morning: *Electricity Use in Residential Buildings*
- S. Nadel

Electricity Use in Commercial Buildings
- M. Levine

Afternoon: *Commercial-Sector Spreadsheet Scenarios*
- J. Busch, E. Mills

DAY 8: IMPLEMENTATION OF ELECTRICITY CONSERVATION STRATEGIES

Morning: *Energy Policy Issues for Buildings Energy Conservation*
- M. Levine

Implementation Strategies for End-Use Electricity Conservation
- S. Nadel

Afternoon: *Analysis of Implementation Strategies*
- S. Nadel

DAY 9: PRESENTATIONS AND DISCUSSION

Morning: Working session
Afternoon: Participant presentations (developed during workshop)

DAY 10: FOLLOW-ON, EVALUATION, CLOSING

Morning: Discussion of follow-on activities, workshop evaluation

Closing Statements
- Woraphat Arthayukti, Energy Research and Training Center, Chulalongkorn University, Bangkok
- Mark Cherniack, Director, Asia Office (Bangkok), International Institute for Energy Conservation
- Deborah Bleviss, Executive Director, International Institute for Energy Conservation, Washington, DC

Participants' Response
- Surapol Dumronggittigule, Faculty of Engineering, Chiangmai University, Chiangmai, Thailand

Appendix D

WORKSHOP RESOURCE MATERIALS

Primary Materials

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