Technical Session IV: Energy, Environment, and Economics
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A wide variety of topics in energy, environment, and economics are covered by the 15 papers in this session. The main focus of all the presentations was energy use. About one-half of the papers extended the energy aspects to include environmental impacts, and about one-fifth of the papers included economic considerations. It is encouraging to see the increasing inclusion of environmental and economic implications in these studies of energy technologies.

The subject matter ranged from individual components to entire communities. One-quarter of the papers were concerned with the performance of specific energy consuming components, and the discussion and results were mainly concerned with technical details and energy use. One-half of the papers dealt with the building and its heating and cooling systems. The building envelope was the subject of two papers, five were concerned with the HVAC system, and in two papers the integration of the energy system with the building was discussed. Finally, one-quarter of the papers dealt with global aspects of energy use at the regional level. The results for most of the papers were obtained through engineering calculation techniques. There were three experimental studies that demonstrated the application of innovative technology in energy consumption.

There were four papers that were concerned with energy use at the level of a specific piece of equipment. Papers # 195 and # 31 were concerned with boiler operation. In paper # 195 a system for the control of combustion was developed and tested. The goal of the controller was to minimize the amount of excess air and soot formation, which would then yield maximum efficiency. The chemical compounds in the combustion region were sensed optically and dampers were then regulated to control the incoming air. The system is robust and can increase boiler efficiency about ten percent. This is a promising method of control. Boiler maintenance and replacement were the subject of paper # 31. The implications of boiler oversizing and part-load operation on energy use and environmental impact in the European Union was discussed. It was estimated that 11,000,000 boilers should be replaced, which would reduce energy consumption and CO_2, NO_X, SO_2, and particulate levels significantly. Another positive impact would be the creation of new jobs. Legislation is a mechanism to produce the needed changes.

Two papers dealt with design methods of specific equipment, and should lead to lower energy use. In paper # 164 methods for estimating the annual energy performance of heat pumps was presented. The method is based on a utilization factor that accounts for internal and solar gains. By including the thermal capacitance and envelope conductance

of the building the annual energy use for a given installation can be estimated accurately. Hydraulic systems were the topic of paper # 355. Current design of the heating or cooling distribution system is based on full load conditions. Most systems operate at part-load much of the time and this needs to be considered in design. Guidelines were given for design.

A major factor in the energy use in buildings in the design of the envelope, and two papers focused on this aspect. Paper # 27 used a typological analysis to divide the buildings in Buenos Aires, Argentina, up into 17 different sets, and then evaluated the impact of envelope improvements. Conservation measures that included ceiling and wall insulation, glazing, and infiltration control were found to reduce heating consumption 7.6 %. There were significant direct and indirect impacts on airborne pollutants (SO_2, NO_X, particulates) for the city. In paper # 224 the insulation requirements for new buildings was considered using a life cycle cost approach. The curve of life cycle cost, which included the costs of both purchasing insulation and the cost of the fuel, was found to be very flat in the region of optimum insulation. Guidelines were given for the optimal levels dependent on fuel type. Policies based on these studies could lead to significant improvements.

Two papers focused on the overall design of the heating or cooling system. In paper # 4 the impact of different cooling systems on the total environmental warming index (TEWI) was determined. The optimal cooling system was the one that minimized the TEWI. A cogeneration plant with a heat driven multi-effect absorption chiller was found to have the lowest TEWI, and provided a significant reduction (20%) over the conventional electrically driven centrifugal chiller. Gas fired absorption units were comparable to conventional systems. The combination of thermodynamics and economics, termed "thermoeconomics" was introduced as a design tool in paper # 288. In this method costs are based on the exergy of the energy flow, both heat and work. Exergy is the potential to produce work and reflects that work has a higher thermodynamic value than heat. The optimal design of an HVAC is one that minimizes the life cycle exergy cost. The approach was demonstrated for a complicated and detailed HVAC system using a modern equation solving routine to facilitate optimization. Significant improvements in design were demonstrated.

Ventilation of outdoor air was the subject of three papers. In paper # 215 the basic ideas of using sensible and latent energy recovery heat exchangers to reduce the energy required to process outdoor air was discussed. Paper # 334 dealt with the CEN ventilation standards and their application to the variety of building classes and internal emissions. The need to consider the specific building was discussed. The impact of outdoor air on the relation between heating and cooling requirements was considered in

paper # 352. For the specific climate types considered (Madrid, Spain and Porto, Portugal) increased ventilation was found to primarily affect heating requirements. Some cooling benefit could be obtained in Madrid through control of outdoor air. These studies demonstrate the complexity of the interaction between energy use and indoor air quality, and the need for further work in this area.

Two very interesting studies were presented on the energy use and environmental impact of buildings in which innovative cooling systems had been installed. The HVAC system installed in the RTBF Hainaut Building in Mons, Belgium, is described in paper # 16. In addition to a cogeneration system there is a boiler, an absorption chiller, and a compression chiller. The control of the cogeneration system has allowed a significant (30 %) shift of electrical demand from daytime to nighttime and reduces the overall energy use. The payback of the system is estimated to be 5 years. The "Next 21" future housing building in Osaka, Japan, is described in paper # 122. The multi-story apartment complex is innovative in construction, with an earth covered roof that damps out the cooling load through it, an ecological garden in the interior, and passive solar heating techniques. The mechanical system is likewise innovative, with a fuel cell, two absorption chillers (one gas fired and one heat driven), photovoltaic cells, and batteries for electric storage. The operation of the building and its heating and cooling system was compared to comparable conventional systems. Energy consumption was reduced 27 % and NO_X by 74 %. These buildings may serve a prototype for future developments.

Global impacts of different measures to provide for building utilities were discussed in two papers. The impact on energy use of new heating systems was considered in paper # 82. Reduced envelope conductance and attention to solar gains has reduced heating energy needs. Heating systems that account for the daily load variations and that respond rapidly to changes are needed. In paper # 117 the impact of solar domestic water heating systems in Chambery, France, was determined. By covering 30 % of the available roof area with solar panels the energy for water heating could be reduce 40 % and the direct emissions similarly reduced. At present, this approach would not be cost effective.

In summary, a wide range of topics were presented. Many studies dealt with the need to continually and incrementally improve the energy use characteristics of buildings. This is an area that will involve with time, and simulation methods are proving increasingly important in designing and evaluating new developments. The two innovate building systems provide an opportunity to test the role of future technology. There is a need to further design and evaluate systems that integrate heating, cooling, electricity, and other utilities. This is a promising area and one in which considerable future research is needed.

Several studies included the environmental impact of heating and cooling technology on chemical emissions and atmospheric warming. These indirect effects of energy use are of increasing importance in energy analysis. The boundaries of policy making needs to be expanded to incorporate these important impacts.