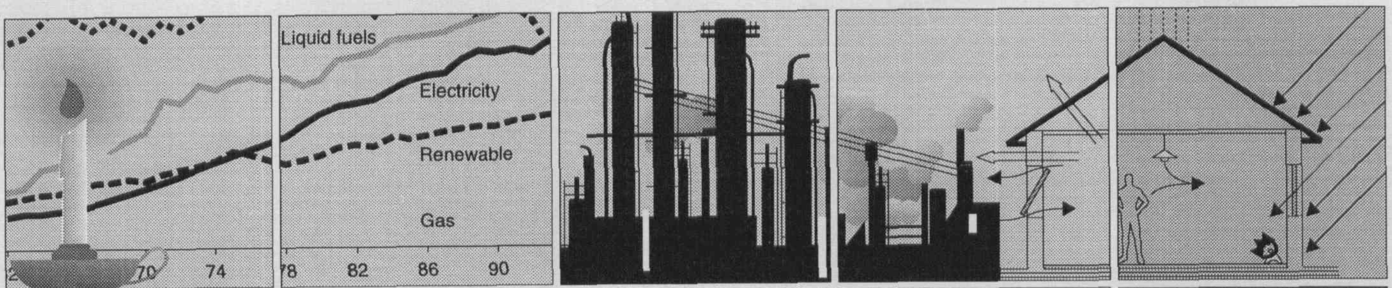
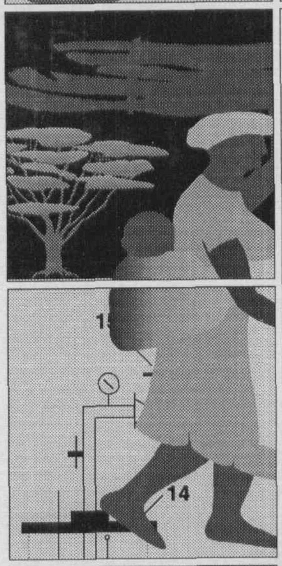
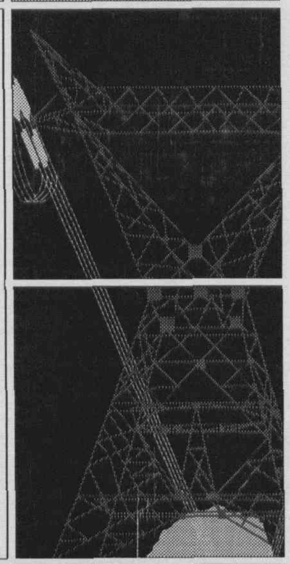
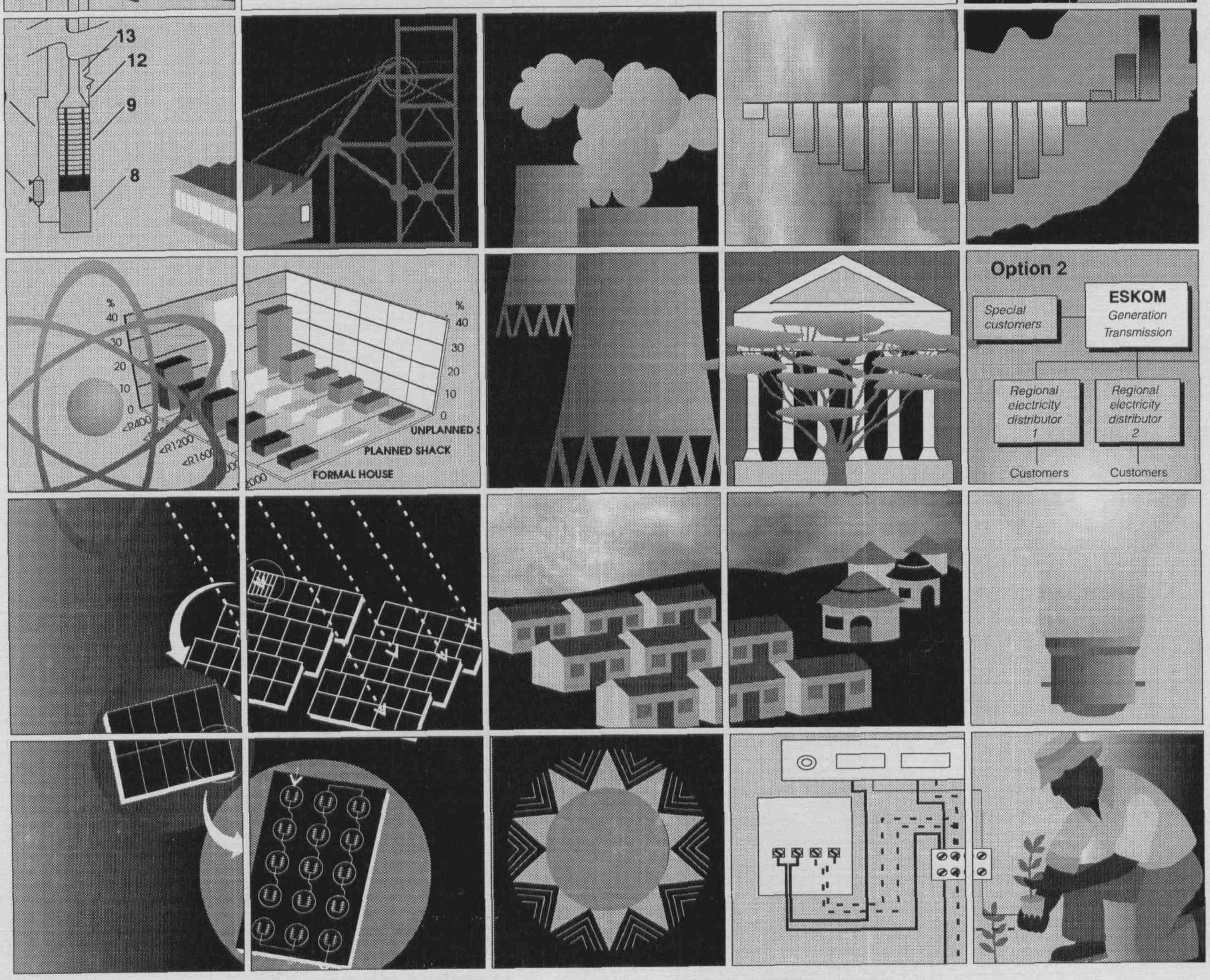




International energy efficiency experience
Lessons for South Africa

GILLIAN SIMMONDS





EDRC REPORT SERIES

ENERGY & DEVELOPMENT RESEARCH CENTRE

University of Cape Town

International energy efficiency experience: Lessons for South Africa

Gillian Simmonds

This report was prepared as part of the project entitled 'Energy efficiency, equity and the environment: Improving access to energy services for the urban poor of South Africa.' The project is funded by the International Development Research Centre and Eskom, whose support is gratefully acknowledged.

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EXECUTIVE SUMMARY

1. Introduction

This report forms part of a three-year policy-oriented energy efficiency research project entitled 'Energy efficiency, equity and the environment: Improving access to energy services for the urban poor of South Africa' (E4) which aims to develop energy efficiency/ demand-side management (DSM) strategies for specific application to poor urban households. It evaluates the international experience in energy efficiency and documents the different strategies and programmes which have been implemented with varying degrees of success. The aim of the report is to provide a resource document from which strategies and policies appropriate or adaptable to the South African situation can be identified.

While the report aims to document as a wide a range of international experience as possible, it draws mainly on the experience of the industrialised countries because their experience in energy efficiency policy is more widely documented. Furthermore, notwithstanding the importance of addressing the energy mix when addressing end-use efficiency in low-income households, the focus is mainly on electricity end-use owing to the fact that there is little precedent for the implementation of non-electric energy conservation measures in the international literature.

2. Integrated energy planning and an end-use-orientated approach

Integrated energy planning (IEP) can be defined as 'a series of steps or procedures by which the myriad of interactions involved in production and use of all forms of energy may be studied and understood within an explicit analytical framework' (Munasinghe 1990: 2). The aim of IEP is to produce and use energy more efficiently so as to maximise net economic output and growth, while balancing economic efficiency with social goals and development objectives such as meeting basic needs. Thus, energy strategies should be compatible with and contribute to the solution of other major problems - including addressing issues of energy and cash poverty, environmental degradation, balance of payments deficits, national energy security and global climate change.

Energy efficiency improvements can be achieved by considering all aspects in the provision of energy services. By taking into account both demand- and supply-side measures, as well as all impacts, including environmental and social, resulting from the generation and distribution of energy, IEP aims to provide end-users with energy services at the lowest cost possible (Miller et al 1994). Such an approach requires the consideration of both new supply options and mixes and more energy efficient technologies and end-use practices. A range of policy instruments can be used to achieve the objectives of IEP. These include:

- physical controls;
- technical methods;
- investment policies;
- education and promotion;
- financial incentives; and
- regulatory, market and institutional reforms (Munasinghe 1990).

3. Barriers to implementation

There are a number of financial, economic, behavioural, technological and policy barriers to the implementation of energy efficiency improvements. These include:

- lack of energy efficiency products and technologies on the market;
- lack of current and credible information on the latest energy efficient technologies and the performance and savings of these technologies for energy decision-makers;
- separation of responsibilities for making capital investments and paying operating costs;
- first-cost sensitivity;

- lack of finance for energy efficiency initiatives;
- energy price distortions;
- lack of adequate institutional capability; and
- policy and regulatory disincentives.

Government, utilities and private energy service companies need to coordinate their activities, implementing complementary energy efficiency programmes and strategies which overcome these barriers and enable the adoption of an end-use-oriented approach to the provision of energy services.

4. Energy efficient technologies

Energy efficient measures and technologies provide opportunities to reduce household energy consumption, thereby improving equity of access to energy and other services and reducing environmental and health impacts of energy generation, distribution and consumption. It is essential that technology does not lead energy-efficiency investment and development. Rather, an end-use oriented perspective should be engaged to identify household energy end-uses and to select the best means of meeting those energy needs. Energy-efficient technologies should be appropriately employed to reduce the most consumptive household end-uses. There are two main arenas in which technologies can be applied to reduce household energy consumption: design techniques to improve the thermal efficiency of the building, and technological improvements in the energy efficiency of appliances.

4.1 Thermal performance of housing

In all climates, buildings constructed according to sound principles of climatic design can reduce the need for artificial heating and cooling by using solar energy available at the site. Many of these climatic design techniques are 'no cost' techniques, requiring only climatic design knowledge. In addition to resulting in long-term energy cost savings for the building owner, buildings designed to take advantage of the solar energy, are more comfortable (Watson 1983).

The thermal performance of the dwelling structure can be manipulated by employing measures which pertain to either the planning of the site or the building envelope. The planning of the site involves using windbreaks, plants and water, indoor and outdoor rooms and earth sheltering. The thermal control of the dwelling through the manipulation of the building envelope involves the employment of solar walls and windows, the thermal envelope, sun shading and natural ventilation (Watson 1983).

It is much cheaper and simpler to install conservation measures while a house is being built than to retrofit these measures later. At the time of construction, conservation measures can be installed for only the incremental cost beyond standard building practices. New construction conservation opportunities are often referred to as 'lost-opportunity' resources, because, if the conservation measures are not installed at the time of construction, then those opportunities may be forgone. Residential new-construction programmes have ranged from simple information programmes to comprehensive programmes that include education, codes and standards, technical training and financial incentives (Nadel 1991).

A variety of low-cost passive solar design measures were identified as a means to reduce energy consumption associated with cooling in Thai houses, while retaining the thermal comfort of the structure at desirable levels. They include the architectural design of the building (such as orientation of building, size and orientation of windows, thermal mass, shadowing devices and earth cooling), landscaping, and simple low-cost measures such as insulation, radiant barriers, reflective paints and reflective windows. To promote and encourage the adoption of these measures in new residential housing, an energy building code was suggested. It is expected that such a code will substantially reduce cooling needs in Thailand's future residential building stock (Nadel 1991).

Although the application of building codes to new residential housing can effect large savings in future energy consumption, the larger proportion of the housing stock consists of existing houses and, therefore, there are a lot of energy savings to be achieved through making thermal performance improvements on the existing houses. In the United States, low-income weatherisation programmes have been introduced to ease the burden of energy costs on low-income households. These programmes have been implemented by both government and utilities. Two million households were weatherised under the DoE programme between 1974 and 1989. Annual energy savings from these programmes have been estimated as between 6% and 10%. Utility-sponsored low-income weatherisation programmes can reduce bad debts and potentially address the low-income bill-payment problem. The types of measures installed by utility programmes in the United States have varied significantly from low-cost measures such as water heater insulation and weather stripping to attic and wall insulation. Annual energy savings for gas-heated homes have been estimated as ranging between 6% and 23% (Schlegel et al 1991).

4.2 Energy efficient appliances

In households in developing countries, the majority of energy usage tends to be channelled toward the intertwined activities of cooking, water-heating and space-heating or -cooling (Sathaye & Tyler 1991). A number of different energy sources are used to meet these energy end-uses. The fuels utilised to meet these needs vary substantially in terms of income and cost and availability. There is a tendency for lower-income households to rely on 'traditional' biomass fuels to meet the multiple end-uses of cooking, water-heating and space-heating. The reasons for this are that electric cookers are often incapable of providing the correct facilities for traditional meals, cooking and space-heating requirements can be met simultaneously through the use of alternative fuels, capital costs may inhibit purchase of electric or gas cookers, and operating costs of electric or gas cookers may be substantially greater than those of alternative energy sources. Thus, policies associated with meeting these energy needs must be based on an end-use oriented approach seeking an optimal mix of fuels to best meet these needs both in terms of efficiency and economic ability.

In low-income households, the most common use for electricity is lighting and, therefore, many energy-efficiency programmes in developing countries have targeted the poor by focusing end-use efficiency on lighting. Furthermore, there are low costs associated with achieving energy saving potentials in lighting, making these programmes the most widespread among demand-side management activities carried out by the electric utilities (Menanteau 1994). The objective of these programmes is to replace widely-used inefficient incandescent lighting with more efficient incandescents and compact fluorescent lights.

Refrigerators are one of the first major electrical appliances that poor people buy. Where their use is growing, they are putting enormous strain on the electricity supply. Rapid growth in electricity generation capacity is needed to supply the domestic refrigeration demand. It is thus essential that energy-efficient refrigerators are promoted and fostered. In 1984, Brazil initiated a refrigerator efficiency programme consisting of efficiency-testing and -labelling. The electricity consumption of residential refrigerators was reduced through improved insulation, more efficient motor-compressors and modified design of the refrigeration cycle. In 1990, Brazil proposed minimum efficiency levels for refrigerators through agreements between the government and manufacturers, requiring that by 1993 refrigerators in each category consume no more than the most efficient model available in 1989. The proposed agreement calls for efficiency improvements of 5% per annum from 1994 to 1998 and will lead to the 1998 models using only half as much electricity as those sold in 1990 (Dutt n.d.).

The mere existence of energy-efficient models that are cost-effective to own and operate does not mean that consumers will make economically rational decisions. Even mandatory labelling of the energy efficiency did little to improve the purchase of energy-efficient refrigerators in the US. Therefore, Dutt (n.d.) argues that for energy-efficient refrigerators to penetrate the market, the efficiency of new refrigerator models must be tested and either minimum efficiency standards must be set (as in the United States) or manufacturers must agree on efficiency protocols (as in Brazil).

Other appliances vary substantially in their contribution to household energy consumption. In industrialised countries, appliances such as televisions, fans, dishwashers and washing machines may contribute a substantial amount to the energy consumption of the household. In low-income houses in developing countries, however, they contribute very little. The energy-efficiency of these products should still be promoted, but it is essential to first target those appliances which will have the greatest impact on household energy savings. It is those appliances that are most energy consumptive that will be the easiest and most cost-effective to target in terms of energy efficiency policies and programmes.

5. Policy options

To exploit energy efficiency to the full, an effective framework which achieves the right balance between regulatory instruments (for example, minimum efficiency standards for buildings and appliances) and market-based instruments (for example, financial incentives) needs to be established. Education and awareness-raising initiatives need to be run simultaneously to promote and enhance the effectiveness of these incentive and regulatory programmes (Collins 1991). The policy options identified are categorised into four main arenas - information programmes, incentive schemes, regulation and price restructuring.

5.1 Information programmes

When implemented alone, information programmes have had minimal impact compared to programmes which offer either financial incentives or regulatory constraints. Information is, however, an essential component of any DSM programme. It is not only vital to the successful manufacture, installation and market penetration of energy efficient products, but also enhances the effectiveness of financial incentive and regulatory programmes through improving end-user awareness. There are a number of different types of information programmes which have been employed to promote energy efficiency strategies and technologies. These initiatives can be classified into five main categories:

- appliance labelling;
- energy audits;
- education and training;
- general information programmes; and
- research and development.

5.1.1 Appliance labelling initiatives

Appliance labelling initiatives, in conjunction with appliance efficiency standards and appliance testing and certification programmes, can have a profound impact on the adoption of energy efficient products. The primary goals of appliance labelling initiatives are to increase awareness of energy consumption and the potential for end-use efficiency, and to provide unbiased information to aid the purchasing decision (IEA 1989). It is expected that, through raising the awareness among end-users, purchasing practices will shift toward more energy efficient products, thereby expanding the marketplace for these types of products and speeding up the commercialisation of new technologies (Casey-McCabe & Harris 1995).

Internationally, appliance labelling programmes have enjoyed varying degrees of success. Some of the important issues emerging from the literature are:

- the labelling programme must take into account who the most influential players are in terms of appliance purchasing and efficiency improvements, and must target them (for example, the success of the programme may not result from end-user choice, but rather from the manufacturer responding to the programme as a challenge creating more efficient products);
- information about and *promotion* of the labelling programme is vital to its success;
- appliance efficiency testing should be *standardised*, either by agreement between the manufacturers or by establishing a national testing programme, which should include the testing of imported equipment so that the accuracy of the energy efficiency information is unquestioned, thus allowing for easy comparison;
- product energy efficiency should be tested by an independent, unbiased source to ensure that energy efficiency data is an accurate representation of the product's attributes;
- the format of and information on the label is essential to the success of the labelling programme - the content of the labels must be clear, visible and easy to understand and the most appropriate measures of comparison must be employed; and
- where compliance is voluntary, as in Brazil, close collaboration between the implementing agency and manufacturers (on setting priorities for the programme and negotiating standards) is essential to the programme success.

5.1.2 Energy audits

Energy audits provide information on the energy consumption characteristics of end-users by doing a detailed survey of energy used and by indicating ways of reducing energy bills. Energy auditing schemes are relatively labour intensive and can, therefore, generate employment fulfilling objectives of development and social upliftment (Jordal-Jørgensen & Larsen 1995). There are a number of key issues which emerge out of an evaluation of energy auditing:

- audits conducted by trusted agencies, such as community organisations, are likely to receive more positive responses from the participants (Nadel 1991);
- simplified auditing schemes are more cost-effective; and
- higher participation rates are experienced where financial assistance is provided and where arrangements are made to help end-users receive assistance in installing energy efficiency measures.

5.1.3 General information and training programmes

Building the capacity of energy efficiency implementing agencies and staff is vitally important to the successful application of energy efficiency improvements. Training of energy auditors, energy managers, inspectors enforcing efficiency regulations, building designers and architects, utility and government staff who plan and operate efficiency programmes and those who provide technical assistance as part of energy conservation programmes is required (Nadel et al n.d.). This training can occur in a number of forms, ranging from seminars and workshops to post-graduate degree programmes at technikons and universities. Ideally, training programmes should be linked to other programmes, providing training for staff around the necessary technical skills, implementation and operation of such programmes.

The provision of *general energy conservation information* through brochures and television advertisements can raise public awareness, but is unlikely to have an effect on actual end-user consumption behaviour unless it is part of a comprehensive effort including technical assistance, correct pricing signals, financing and efficiency regulations (Nadel et al n.d.). These programmes are most effective when they provide end-users with simple and specific steps to take along with estimates of how much energy and money can be saved and when the information is provided by a trusted and respected organisation whose motives are clear and unambiguous. Energy information centres can be set up to provide such information.

5.1.4 Research and development initiatives

Research and development is very important to the development and adaptation of new and existing energy efficient technologies. Research around the energy efficiency issue should not, however, be limited to technical energy issues, but should include policy, social and economic research so as to discover the ways in which energy uses interrelate with social and economic needs and to find new and more effective ways of reducing energy consumption, while promoting social and economic development. Government energy R&D expenditure is important for a number of reasons (Greenpeace 1992):

- it sends important signals to industry, manufacturers and the energy market about energy policy directions and objectives;
- it can accelerate the development of new technologies;
- market barriers, such as the pricing of coal- and nuclear-based electricity below their long-run marginal cost curves and government subsidies of these energy sources, inhibit the entry of energy efficiency technologies into the energy market and, therefore, it is necessary for government to correct these market failures; and
- the private sector is often unwilling to undertake the large-scale investment necessary for a technology to become economically viable.

5.2 Economic Incentives

Economic incentives can be used to encourage manufacturers, end-users and suppliers to make energy efficiency investments. They should be considered temporary measures to mobilise end-users, to prepare regulation or to promote energy efficient technologies by creating a market that would not exist without the incentives (Lapillonne 1993).

5.2.1 *End-user incentives*

End-user incentives should, in principle, relate to actions that are cost-effective from the point of view of the societal good, but would not be undertaken by end-users for a variety of reasons, such as poor information, lack of capital to overcome first costs and split incentives. Different consumer groups respond to different types of incentives (Mills 1991). It is essential, therefore, that the programme incentive package is informed by the socio-economic circumstances and end-use preferences of the target group. The most commonly applied incentive schemes for low-income target groups are grants, leasing and give away and direct installation programmes.

Zero-interest or low-interest *loan programmes* can be provided for end-users to obtain the capital necessary to make energy efficiency improvements. Such loan programmes have been implemented with varying rates of success. The results of these programmes show that zero-interest loans result in higher participation rates than low-interest loans, and that end-users, especially low-income groups, generally prefer grants to loans. These are, however, difficult to administer.

Grants are direct or indirect payments to an individual or class of end-users, which give the recipients a financial incentive to purchase a particular good or service. Grants have targeted low-income end-users, with the aim of encouraging their participation in energy efficiency programmes, by aiding them in overcoming first-cost sensitivity. Grants have elicited high participation rates and have been successful in creating awareness, providing information to end-users and improving financial attractiveness of energy efficient measures. However, they are administratively expensive and costly (IEA 1989).

Leasing has been employed in programmes which target risk-averse and cash-poor residential people to overcome the problem of end-users being unable or unwilling to make the high initial investment for buying the product. There are many examples of leasing with regards to compact fluorescent lightbulbs (CFLs). These programmes allow the end-user to spread the payment for CFLs over their electric bills and have resulted in high participation rates where accompanied by information programmes. They result in substantial energy savings with little cost to the implementing organisation (Menanteau 1994).

Give-away programmes have resulted in the highest penetration rates of all the different incentive options employed (Mills 1991). These programmes are generally most successful when community-based organisations are involved in the marketing of the energy efficient technology. These give-away programmes are often linked to *direct installation programmes* where utilities or third party companies offer installation services to the end-users, thereby minimising the barriers to end-user participation of lack of time, money or expertise to install the measures themselves (Nadel et al n.d.). Direct installation programmes increase the penetration of energy efficient measures into the market by offering a comprehensive service which can include installation, auditing and financing. Furthermore, they ensure that potential energy savings are maximised by allowing for professional installation and consultation.

5.2.2 *Manufacturer and energy supplier incentives*

Manufacturer incentives encourage the development and marketing of energy efficient equipment by overcoming market barriers such as negative regulatory prices and imperfect information. One such method which has been successful in transcending these market barriers is that of *technology procurement*. Technology procurement is the process of a purchaser attempting to accelerate development in a desired direction by pledging future purchases of something that did not exist at the time. Demand is created by bringing together important customers and formalising and expressing their requirements (Nilsson 1993). The feasibility of effectively influencing the markets is influenced by the following:

Utilities are unlikely to undertake energy efficiency improvements unless the right regulatory and economic environment exists. Positive financial incentives may be necessary to ensure that utilities consider end-use energy efficiency investments as viable business alternatives to supply-side investments. These supplier incentive schemes include:

- policies designed to allow utilities to recover the costs associated with their demand-side management practices, either by treating the cost of the DSM programme as an operating cost and allowing the full costs to be recovered during the year of expense or by treating the cost of the

DSM programme as an asset and allowing the cost of the programme to be paid over time with an associated rate of return;

- shared savings, where the utilities are allowed to retain for their shareholders a predetermined portion of any savings realised through their demand-side management practices;
- policies which allow utilities to earn a bonus return from demand-side management practices, for example, utilities receive a higher rate of return on DSM investments than they would achieve if they invested in the supply-side (rate base premium) or utilities receive a bonus per unit of resource saved in excess of some nominal goal (performance premium); and
- policies which decouple profits and sales, so that utilities are no longer penalised for lower revenues from DSM programmes and have no incentive to maximise electricity or gas sales (Woolf & Mickle 1993; IIEC 1994b; Sioshansi 1994).

5.3 Regulation

Minimum efficiency standards for buildings and appliances result in more rapid and quantifiable energy efficiency improvements than do financial incentives. If based on reliable assessments of what is technically and economically reasonable for manufacturers to achieve at a cost beneficial to the end-user, they can successfully achieve defined performance improvements within predetermined time-scales, thus forcing product development to occur at a faster pace than would otherwise have occurred. There are, however, limits to what regulations can achieve. For example, construction codes and minimum efficiency standards for appliances are cost-effective methods of gradually cleansing the market of inefficient and inferior products, but it is difficult to persuade end-users to replace their existing appliances with super-efficient ones until the old ones wear out (Sioshansi 1994). End-user rebates and other incentives can accelerate the turnover rate of old appliances and increase the market penetration of newer, more efficient ones.

5.4 Price restructuring

Electricity prices in developing countries have historically served economic development, with artificially low prices promoting the development process (Levine et al 1992a). Historically, energy prices have seldom reflected the social, environmental and full economic costs of generation, distribution and consumption and, consequently, market failures have occurred, resulting in the misallocation of resources. There is a real danger in South Africa that electricity prices will continue to be kept low to effect both economic and social development, thus encouraging excessive energy consumption. Cost-reflective energy pricing signals are important for the efficient allocation and use of the resource. Without the correct pricing signals, it is impossible to create an environment in which energy efficiency policies and programmes can work. Thus, it is important that the electricity pricing structure is adjusted to generate the right signals to end-users, manufacturers and government in South Africa.

Electricity price reform can be effected in two ways. Firstly, through adjusting total cost to reflect the real costs of providing the energy service and, secondly, through altering the tariff structures to reflect the temporal differences in costs of energy provision and/or to penalise those with high consumption levels.

5.4.1 Increase electricity price

Higher energy prices motivate energy efficiency actions. When energy prices are stable and low, it takes much more effort to sell the concept of energy efficiency (Sioshansi 1994). Energy prices need to be restructured to reflect the real costs of providing the energy services. This will give the right signals to energy decision-makers, encouraging the adoption of end-use energy efficiency measures and stimulating the development of energy efficiency technologies. Care must be taken to minimise the burden on the poor of increasing energy prices.

5.4.2 Restructure tariff rates

Residential interruptible rates require substantial involvement from utilities. Fitting of radio control units to each appliance in the programme is potentially expensive and complex and, therefore, unsuitable for South Africa.

Time-of-use (TOU) rates are cost-based electricity prices which include temporal considerations. The principle is that end-users are billed at lower rates during nighttime, weekends, holidays and summer (off-peak periods) and at higher rates during daytime, work days and winter (peak periods). The aim of TOU rates is to encourage end-users to shift electricity use to off-peak times, reducing electricity use at peak times and scheduling new electricity uses away from high-use periods. In this way TOU rates are used to flatten electricity demand, using generating stations more efficiently and reducing the need for more generating capacity. The TOU rates not only benefit the utilities, but also customers who can save money by planning electricity use during off-peak hours to take advantage of the cheaper rates. This rate system does not improve equity, as no cross-subsidisation occurs from the wealthy to the poor, but it does improve efficiency and thus should be considered as a viable option (Pickering 1994).

Increasing block rates are where prices increase at high levels of electricity usage, penalising excessive over-consumption. Furthermore, the initial block can be designed so that energy is affordable to low-income users (Levine et al 1992). In this way, cross-subsidisation from rich to poor households can occur. This type of rate may not be consistent with the cost of service-based rates, but it can be a powerful incentive for conservation (Nadel et al n.d.). The pitfalls with this form of tariff structure are that: firstly, it deliberately fails to allocate costs equitably; secondly, its complexity might lead to confusion among end-users; and thirdly, international experience has shown that increasing block rates are open to political interference, resulting in an increase in the size, or a decrease in the rate, of the low rate block over time (Pickering 1994). Increasing block rates is not considered to be an effective option as they require regulation to ensure they are free of abuse from political manipulation.

The *flat rate tariff* has been singled out as the most effective option for South Africa. While it is considered to be less equitable than the increasing block tariff, it is simple to both implement and understand. It is generally designed so that the average consumer would pay the full cost of supply each month. Households consuming less than the average number of units per month would be subsidised by some amount, while consumers using more than the average number of units would pay an additional amount above the cost of supply. Thus, it allows for redistribution of funds from the wealthy to the poor, while retaining a relative efficiency for reflecting service-based costs (Pickering 1994).

6. Conclusion

The paper concludes that, within the South African context, there are four main areas in which residential energy efficiency improvements can be made. These are price restructuring, thermal performance of housing, appliance efficiency and fuel choice. These areas have been identified as the most appropriate to the South African context because of the opportunities afforded by the RDP for immediate implementation of such strategies and/or because they are considered a necessary component of a national residential DSM programme.

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CHAPTER ONE

Introduction

1. Background

This report is part of a wider project entitled 'Energy efficiency, equity and the environment: Improving access to energy services for the urban poor of South Africa' (E4). The E4 project aims to improve access to efficient energy services for the poor communities of urban townships and to increase the affordability of such services through improving household end-use efficiency. By suggesting options for managing an expected increase in electricity demand, the project aims to mitigate the potentially adverse environmental effects which may result from increased generation of coal- or nuclear-based electricity. Finally, by encouraging greater efficiency in the use of household fuels, the project aims to reduce the local environmental and health risks resulting from the use of fuels such as wood, coal, gas and paraffin, all used as an alternative to electricity. Integrated energy planning (IEP) and an end-use approach to energy efficiency provide a method to achieve these goals. The specific aims of the E4 project are:

- to develop a demand-side management (DSM) strategy for specific application to poor urban households, including programmes which could be delivered both by electric utilities and by government and/or energy distributors; and
- to encourage an improved capacity to develop, plan and analyse energy efficiency programmes, particularly DSM management options in South Africa, giving special attention to disadvantaged and poor communities.

The following international review of household energy efficiency policies and programmes is the first of three initial research components in the E4 project. The second component of the initial study is a review of the energy needs and existing energy efficiency interventions among poor urban households in South and Southern Africa. The third component is a study of the costs and benefits of interventions in the different sectors of the energy community.

2. Scope and purpose of report

This report evaluates the international experience in IEP and DSM, specifically focusing on those programmes and strategies which deal with energy efficiency and energy utilisation among the urban poor. Through assessing the wide variety of programmes that have been implemented in both industrialised and developing countries, it is possible to identify those strategies and policies which are appropriate to the South African situation and those which display the potential to be modified or adapted to suit the local context.

The selection of literature for review was based on the comprehensiveness of available documentation, with regard both to the policies and programmes employed, and the results of those strategies. The paper, therefore, focuses mostly on the industrialised countries' energy efficiency programmes because these countries have had more experience with energy efficiency policy; their programmes, having come to fruition, show clear results. Few developing countries have implemented energy efficiency strategies and even fewer strategies have borne results. The paper does, however, detail the DSM proposals of those developing countries and report the results of ongoing projects where these have been documented in the literature.

The scope of the report is limited by the E4-project's focus on the residential urban poor, and by the international focus on electricity end-use. These foci are detailed below.

2.1 Target sector

DSM and energy efficiency strategies have focused on various economic sectors, such as transport, commerce, industry, agriculture and residential. Despite the fact that the household sector is not the largest consumer of energy of these sectors, this report nevertheless focuses on it. The policies and programmes considered, also, are those which relate to the efficiency of household energy and, specifically, electricity use. The reasons for this include:

- internationally, and in South Africa, the household sector often constitutes the smallest but fastest growing portion of the electricity load;
- the household sector is the main contributor to the peak energy loads which occur during the evening and in the early morning in most developing countries. In South Africa, although residential electrical energy consumption constitutes only 15% of the total national electrical energy consumption, it constitutes 75% of the variable load (Naudé & Lane 1995). This is significant because satisfying peak load incurs disproportionate capital investment for capacity which is infrequently utilised; and
- with regard to equity considerations, focusing on end-use efficiency at the household level is the logical step toward redressing the huge disparities in South African society both in access to energy and in the level of services provided.

2.2 Target group

The principle target group of this project is the **urban poor**, including both electrified and unelectrified households. The project is particularly concerned with the poor because, generally, poor households in South Africa have been denied access to the benefits of affordable, versatile and safe energy sources. Most of the urban poor struggle to secure adequate energy to provide for basic needs - such as cooking and heating - and face a situation of *energy poverty*.[1] Two main scenarios encourage energy poverty: firstly, the range of fuel-choices people have access to may be structurally constrained; and, secondly, the poor, being unable to make the required capital investments to improve on already energy inefficient low-income housing, may face high operating costs for energy. This can be explained largely by the income-expenditure patterns of the poor. These are characterised by extremely short and irregular cash flow cycles, involving small amounts of cash. These patterns suggest that households are able to meet immediate needs only when the cash is available and are forced, generally, to spread income over a range of necessities on a daily basis. This type of income-expenditure pattern presents problems in the provision of energy sources which can only be bought in fixed amounts or those which are billed over a period of time, such as credit metered electricity. It also impacts on the households' ability to surmount the entrance barriers to certain energy carriers, such as the cost of wiring a house for the use of electricity or the cost of electrical appliances. Incongruously, this results in a situation where the poor often spend relatively more than the rich, in terms of time and money, for their energy services (Van Horen et al 1993).

In South Africa, there is a great inequality in access to choices of energy carriers. This is not a result of scarcity of energy resources. On the contrary, South Africa has an abundance of energy: it has the fifth-largest coal reserves in the world and it is the third largest exporter of coal and one of the largest exporters of uranium in the world (Van Horen et al 1993). Rather, the inequality is a direct consequence of the political and economic policies which served the interests of the enfranchised minority in the apartheid era. Furthermore, there has been insufficient policy emphasis on energy efficiency in low-income households. The numbers thus

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[1] *Energy poverty* has been defined as 'the inability to purchase *warmth* and other energy services' (Boardman 1988: 326). The amount of warmth obtained from a fuel depends on the efficiency of two sets of capital stock - the heating system and the building fabric.

suffering from energy poverty have continued to grow and will continue to grow unless this policy issue is addressed.

There are three main policy issues which are relevant to energy efficiency in South Africa.

- Firstly, present building and environmental health standards are inadequate to ensure that houses are thermally efficient. This absence of legislated thermal performance standards impacts on the poor most profoundly because they are unable themselves to make the capital investments required for thermally efficient housing.
- Secondly, the range in cost of domestic fuels, combined with the degree of choice of energy carriers, is the major cause of variations in the cost of warmth and other energy end-uses between the rich and the poor. Great improvements in energy efficiency are achievable only by those households which can afford to undertake fuel substitution, reducing their running costs and increasing the level of controllability. The poor - owing to their irregular cash flow cycles - are generally reliant on more expensive and less efficient fuels to meet their needs. Policies are thus required to ensure that low-income households have access to cheaper and more efficient forms of energy and can use the most appropriate fuel for each end-use.
- Thirdly, at present there are no performance standards that apply to the energy efficiency of appliances in South Africa. Consequently, appliances tend to be highly energy inefficient, contributing to the high levels of demand for electricity and the high operating costs of electrical appliances.

These three policy issues have an impact on the poor, reinforcing energy poverty. Energy poverty results from low levels of investment in capital stocks and can, therefore, be combated most cost effectively through capital investment. One strategy to overcome energy poverty is to invest in energy efficiency in low-income households. Strategies to improve the thermal performance of the dwelling structure, to improve the efficiency of appliances and to ensure the use of the most efficient fuel to meet end-use demand are some of the energy efficiency strategies which can be employed. The South African government, through the Reconstruction and Development Programme, is emphasising the need to achieve equity in access to sufficient and affordable energy resources and it is thus vital that the government address the issue of energy efficiency.

The focus on urban communities was considered to be advantageous for a number of reasons. Firstly, urban and peri-urban communities are generally more accessible, and therefore easier to research, than rural communities. Secondly, these communities are likely to undergo rapid changes in energy use over the next few years and represent the largest segment of the population that will receive improved energy services. They thus present the best opportunity for policy interventions. Thirdly, it is felt that the results of this project can feed into later studies of efficiency in rural households.

The major concentrations of poor urban households are in the metropolitan areas of Gauteng, the Durban Functional Region (DFR) and Pietermaritzburg, Cape Town, Botshebelo (near Bloemfontein), Port Elizabeth and East London. It is estimated that these areas account for roughly two-thirds of the urban poor. These households usually live in the townships, outside of the formerly white cities. In the past few years about half of the formal houses in these townships have been connected to the electricity grid, while most of the informal dwellings remain unconnected. In 1992, only 55% of urban household dwellings were electrified (Van Horen et al 1993).

It must be noted that the poor in these urban centres have diverse lifestyles and energy-use patterns and coping mechanisms are subsequently extremely complex. A variety of strategies is thus required if any success is to be achieved in the widening of access to energy sources for this group of people. This international review emphasises the varied programmes and policies which have been applied to low-income urban communities in both industrialised and developing countries. The socio-economic and locational profiles of the communities targeted in the reviewed low-income residential programmes varies considerably. In the industrialised countries, the urban poor generally have physical access to gas or electricity, and to formal housing. They also have a relatively high level of consumer appliance ownership. The urban poor in the reviewed developing countries have more similar characteristics to the urban poor in South Africa. Here, a mix of formal and informal housing, a low level of household access to electricity, a reliance on alternative fuels,[2] and low levels of appliance ownership are found.

Internationally, low-income groups have been targeted by utilities for special attention. Nadel (1991) cites the following reasons for this:

- all other things equal, low-income customers are less likely to participate in energy efficiency programmes than higher-income customers because the upfront costs and the time involved in adopting energy efficiency strategies precludes their participation. This results in low-income groups actually subsidising higher-income participants in many programmes;
- low-income end-users contribute disproportionately to costs incurred by the utility for bad debts. These debts can potentially be reduced if customers bills are lowered as a result of conservation actions; and
- utilities may decide that offering conservation measures to low-income end-users is a good social policy.

2.3 Focus on electricity

Notwithstanding the importance of addressing the energy-mix when addressing end-use efficiency in low-income households, the international review focuses predominantly on electricity end-use for both those households which are already electrified and those which will be electrified in the next ten years. There are two main reasons for this:

- Evaluation of international experience reveals that there is little precedent for the implementation of *non-electric energy* conservation strategies.
- There is currently a massive electrification drive in South Africa. The government, through the Reconstruction and Development Programme, plans to electrify 2.5 million households by the year 2000, thereby doubling the number of households with access to electricity (ANC 1994). Eskom has committed itself to assisting the government in achieving this goal. This has profound implications for household electricity demand as new connections are made. There is some discussion as to the level of expected demand arising from the new electrical connections that will be made to low-income houses, as the switch to electricity is likely to be gradual.[3] Household demand for electricity will grow, however, especially if incomes rise and appliances are acquired.

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[2] Under Integrated Energy Planning, the energy needs of the end user may be best met by an appropriate mix of fuels. The consumption of fuels other than electricity should, therefore, not be seen as a consistent negative. However, many urban poor are relying on fuels which are not only inappropriate in meeting their energy needs, but also provide additional health risks resulting from air pollutants released into the atmosphere on combustion.

[3] This is because households may still have problems securing adequate energy supplies if the electricity service is too expensive, cheaper fuels are available and if incomes of poor households remain unpredictable and periodic.

3. Structure of report

The paper begins, in Chapter Two, by describing and motivating for end-use energy efficiency and integrated resource planning. The roles of the main players - government, utilities and third parties - in implementing energy efficiency programmes are discussed and the reasons for their involvement are outlined. In addition, barriers to the implementation of energy efficiency programmes are identified and some policy suggestions to overcome these barriers are made. Chapter Three describes the potentially available measures and technologies which are able to reduce end-use energy consumption, thereby improving equity and/or environmental quality.

Chapter Four identifies the policies which have been used to effect the implementation of energy efficiency programmes in both industrialised and developing countries. These include policies surrounding optimal fuel mix, information programmes, financial incentive packages, regulation, price restructuring and finance. Chapter Five elaborates on this, identifying those policies, technologies and strategies most suited for energy efficiency programmes targeted at the residential urban poor in South Africa, and ends by drawing some conclusions.

CHAPTER TWO

End-use energy efficiency

1. Integrated resource planning and an end-use-oriented approach[1]

End-use energy efficiency improvements are often ignored by energy decision-makers because their implementation tends to cut across the traditional institutional boundaries defined by current energy planning (Sathaye & Gadgil 1992). Integrated resource planning provides a different approach to energy planning and encourages the adoption of energy efficiency measures by considering all aspects in the provision of energy services. It aims to provide end-users with energy services at the lowest cost possible, taking into account both demand- and supply-side measures, as well as all impacts, including environmental and social, resulting from the generation and distribution of energy (Miller et al 1994).

End-users do not demand energy but, rather, *energy services*. Therefore, an end-use oriented approach to energy planning is concerned with what energy services are demanded and how best to deliver those services to the users. The focus is thus not on meeting the demand for *fuels*, but on choosing that mix of energy sources which will provide reliable and convenient *energy services* in the most economic and sustainable manner possible, while still meeting the country's economic, environmental and social development targets.

Integrated energy planning (IEP) can be defined as 'a series of steps or procedures by which the myriad of interactions involved in production and use of all forms of energy may be studied and understood within an explicit analytical framework' (Munasinghe 1990: 2) or as the 'means of analysis of all energy issues within a unified policy framework in order to arrive at a set of nationally optimal energy solutions over the long term' (Asian Pacific Development Centre, quoted in Eberhard 1993: 6).

Munasinghe states that 'the broad rationale underlying all national level planning and policy making is the need to ensure the best use of scarce resources, in order to further socio-economic development efforts and improve the quality of life of citizens' (1990: 3). The aim of IEP is argued to be to produce and use energy more efficiently so as to maximise net economic output and growth, while balancing economic efficiency with social goals and development objectives such as meeting basic needs.

The Asian Development Bank advocates an end-use oriented approach to energy planning, directed toward achieving sustainable development (Dutt n.d.). The features of this energy strategy are as follows:

- satisfying basic human needs by directly allocating energy resources;
- creating fair economic comparison between all energy sources and end-uses;
- promoting energy efficiency improvements;
- maximising the use of renewable resources;
- generating new knowledge and technological advances; and
- ensuring compatibility of energy strategies with other global problems.

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[1] This section is based on a combination of Dutt's (n.d.) conception of end-use energy planning and Eberhard's (1993) outline of IEP.

The aim is, therefore, to implement energy strategies which are compatible with and contribute to the solution of other major problems - including issues of energy and cash poverty, environmental degradation, balance of payments deficits, national energy security and global climate change.

More efficient ways of meeting the future demand for energy services can be identified by comparing the technical, consumption and economic details of current and alternative end-use devices. Dutt (n.d.) identifies three groups of strategies as improved ways of meeting the future demand for energy services. These are to employ:

- more efficient end-use devices;
- synergies (technologies that permit simultaneous servicing of several end-uses); and
- new supply options, especially those using renewable and decentralised resources.

Dutt (n.d.: 2) defines this end-use approach as one which 'considers these alternatives as well as conventional technologies to arrive at an optimal mix of centralised and decentralised, renewable and non-renewable supply options, taking advantage of cost-effective energy efficiency measures and synergies of energy conversion'. This approach results in the identification of an energy future that is potentially less capital- and resource-intensive and more environmentally benign.

Munasinghe (1990) takes this a step further, identifying a range of policy instruments which can be used to achieve these policy objectives. These include:

- physical controls;
- technical methods;
- investment policies;
- education and promotion;
- pricing, taxes, subsidies and other financial incentives; and
- reforms in market organisation, regulatory framework, and institutional structures.

These technologies, strategies and policies which are necessary to consider in IEP are detailed in terms of their international application in chapters three and four of this report. This chapter focuses on the institutions necessary for and the barriers to implementation of IEP.

2. Who are the main players in energy efficiency improvements?

It is important that those who are best equipped and motivated to take the necessary measures to encourage the adoption of energy efficiency, are the ones who do it. Apart from the end-users themselves, there are three main sets of institutions which are capable of influencing the market and, thereby, encouraging the adoption of energy-efficient technologies and strategies. These are:

- government;
- utilities; and
- third parties, such as private energy service companies.

There are many other players (such as architects and designers, manufacturers and banks) who have a facilitating role in the implementation of energy efficiency improvements. It is the above sets of institutions, however, which have the ability to coordinate the activities of these facilitators, thus effecting energy efficiency strategies.

There has been some debate surrounding which institutions are the most appropriate for the implementation of energy efficiency programmes. The strengths and weaknesses of these institutions as implementing agencies are discussed below.

2.1 Government

Market distortions and other factors which determine energy end-use efficiency can be corrected through the regulatory framework which affects the strategies of utilities, and through a range of environmental, energy security, fiscal and other policies that affect the allocation of economic resources. McInnes & Unterwurzacher (1991) identify four possible strategies that might be considered by individual governments. These are:

- modifying electricity pricing and other utility regulations to ensure that the correct *price signals* are given to energy users;
- removing any *limitations* to utilities implementing demand-side management activities if these activities yield benefits for both consumers and the utility;
- improving the effectiveness of market forces by ensuring that energy users have access to adequate *information* and advice; and
- offsetting financial barriers to energy-efficient investments by offering selected, though usually temporary, *financial inducements* or by introducing carefully designed efficiency standards.

Thus, it is argued that governments can potentially get involved in three arenas - information generation and dissemination, regulation, and economic intervention.

The level of government involvement is dictated by the economic and political philosophy of the country. In some countries, for example the United States, there is a resistance to state intervention and planning of the energy sector, owing to their free-market philosophy. A degree of state planning is, however, still needed to address the failures of the energy market in the United States and limited state intervention does occur (Eberhard 1993). Where state intervention and planning are limited, end-use energy efficiency programmes are generally considered the domain of utilities and the government tends to play no more than an enabling role.

In other countries, where there is a stronger tradition of governmental activity, there is precedent for the state to get involved in energy efficiency programmes in the arenas of regulation and market intervention. For example, in Denmark there are already taxes on electricity. These taxes could be used to cross-subsidise energy conservation activities, thus presenting the potential for several actors to bid for governmental funds to carry out energy efficiency programmes in the most cost-effective manner (Sønderhousen & Gram 1995).

Further still, in some, predominantly developing countries, government plays a role of instituting and controlling energy efficiency programmes themselves, either independently or through state-owned utilities.

An additional means by which government can stimulate energy efficiency improvements is through their *procurement* programmes. Government purchasing can play important symbolic and substantive roles in initiating or accelerating the development of energy-efficient products and market transformation for specific energy-using technology. The buying power of government in both industrialised and developing countries represents a largely untapped source to stimulate market demand for more energy-efficient equipment and goods (McKane et al 1995). A strategy for energy-efficient product procurement in government would include:

- making the government a leader in buying cost-effective, high-efficiency products;

- ensuring that the results of the government's energy-efficient purchasing practices are documented and disseminated to other market segments to encourage other organisations to change their purchasing practices;
- a comprehensive government purchasing strategy which ensures that energy-efficient government procurement decisions consider environmental impacts and also include functional requirements and life-cycle costs to the direct user; and
- promoting the use of government buying power both to increase the market share of today's energy efficiency products and to stimulate the introduction of new, efficient technologies.

The potential for energy-efficient government procurement practices to influence the energy efficiency market is demonstrated in the example of the United States government in Box 2.1.

Box 2.1

Government procurement in the United States

(McKane et al 1995)

The United States Federal government represents the single largest customer in the world for most energy-related products, spending roughly $10-20 billion per year on energy-related products. Clearly, a huge potential exists for expanding and improving the energy efficiency market by changing government purchasing practices so that they purchase only energy-efficient equipment. Government can also affect the speed at which new energy-efficient products are developed by expressing their demand for and guaranteeing the purchase of energy-efficient products which meet certain specifications and a particular cost. The Energy Policy Act of 1992 directs federal agencies to purchase energy-efficient products that are cost-effective on a life-cycle cost basis and for the Department of Energy (DoE) to issue guidelines which will help other government agencies to identify these products. The Act further directs DoE to evaluate the potential for government purchasing to assist the commercial introduction of new, energy-efficient technologies. This was reinforced by an executive order signed in March 1994 which directs the DoE to cooperate with other federal agencies in a government-wide initiative on energy-efficient procurement. There are four elements to this initiative:

- initiate *best practice buying*, defined as purchasing products which are in the upper 25% of energy or water efficiency or are at least 10% more efficient than the relevant DoE efficiency standard requires;
- help create or expand federal *entry markets* for new technologies through a voluntary inter-agency 'procurement challenge';
- identify opportunities for *early retirement* of older, less efficient equipment in the federal stock; and
- *eliminate barriers* to energy-efficient purchasing.

The response to this programme has included the publishing of catalogues listing energy-efficient products, a coordinated effort to establish a set of performance criteria, a single, government-wide symbol to designate products that are energy-efficient as defined by Executive Order, the definition of specific performance levels for each major type of energy-using product, and the testing and ranking of these products to establish a comparison between existing models on the market. A further result is the recent establishment of a *Procurement Challenge* by the DoE, inviting all federal agencies to 'purchase *best practice* energy-efficient products, to commit funding to provide an entry market for innovative new products or to otherwise show leadership in changing their procurement policies and practices to promote energy efficiency'.

In conclusion, international experience shows that market-induced equilibrium is often incapable of guaranteeing desirable outcomes in the energy system. Instead, selective intervention and planning by the state is necessary to encourage increased energy efficiency for the social good. Furthermore, government has the advantage of central funding to dedicate to energy efficiency practices and the ability to integrate specific actions with coordinated energy policy for the country (Jackson 1992). One limitation of government as an implementing agency is that it does not have a specific relationship with energy users.

2.2 Utilities

In many countries, utilities play the dominant role in fulfilling national goals to improve energy efficiency and reduce environmental impacts of electricity consumption. Sønderhousen and Gram (1995) state that utilities work to reduce customers' demand for their product for three main reasons:

- it is profitable to do so;
- they do so in order to get customer recognition and confidence; or
- they are forced to do so by authorities.

There are arguments both for and against utilities as the major role-players in the introduction of energy efficiency programmes. The following are the extremes in the argument, but a number of proposals fall somewhere between these two extremes or call for a combination of *utility-sponsored*[2] and *mandated*[3] schemes taking place simultaneously (Sioshansi 1991).

Arguments in favour of utility-sponsored schemes state that utilities have strong and unique qualifications to undertake all, or a major component of, energy efficiency investments that are desirable for economic, social or political reasons. Therefore, utilities should be prime players in the growing and potentially profitable business of energy efficiency. The qualifications for involvement in energy efficiency improvements possessed by utilities include the following:

- It is much easier for utilities to finance activities to reduce the demand for energy than other companies which may have the same competence on energy efficiency. The reason is that many utilities are monopolies - natural or otherwise - and can 'force' their customers to finance energy conservation activities whether the customers have an interest in this or not (Sønderhousen & Gram 1995). Utilities are thus in an advantageous position to borrow money or finance conservation investments on behalf of their customers. Consumers can repay the utility for these investments out of savings on energy conserved (Sioshansi 1991).
- Utilities possess a detailed knowledge of the existing demand and supply structure, have a longstanding relationship with end-users, and have the infrastructure to provide specific energy services and bill consumers for them (Jackson 1992).
- Investment in conservation devices can, under the right regulatory conditions, provide utilities with a new means of generating revenues (Sioshansi 1991).

Society reaps the biggest benefits from energy conservation when the activities are optimised in a way that gives the largest improvements of energy efficiency at the lowest costs. As long as utilities are able to provide optimal results, it is argued, energy conservation should be the responsibility of the utilities (Sønderhousen & Gram 1995).

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[2] Schemes where utilities design, implement and reap benefits of energy-efficiency strategies.

[3] Schemes where energy-efficiency implementation is mandated to be undertaken by contractors.

It is questionable, however, whether utilities always deliver the best and cheapest energy conservation. Utilities tend to give preference to investments which are in their own interest, not those which are socially optimal. Furthermore, it has been argued that utility-driven activities on energy efficiency are too expensive. In some cases, this has been a result of regulations dictating the type of activities that utilities can carry out. For example, utilities may have been prohibited from offering rebates to customers and, therefore, the range of measures that they can employ has been restricted. It is also suggested that, under current regulations, utilities do not have sufficient incentives to engage in genuine energy efficiency. Therefore, utilities cannot be expected to do well in energy efficiency implementation.

Mandated energy efficiency programmes have been suggested as a solution to these problems which emerge out of utility implementation. In the extreme-case scenario, mandated energy efficiency programmes would, for example, be managed by *regulated* conservation utilities. Third-parties (for example, independent energy service companies (ESCOs), building and retrofit contractors) would be contracted to the utilities to implement the energy efficiency programmes. Mandatory demand-side bidding procedures[4] would ensure that energy efficiency services are provided by the cheapest and most efficient contractors. Finally, mandated appliance efficiency and building *standards* would encourage the overall efficiency of the appliance and housing stock (Sioshansi 1991).

Sønderhousen and Gram (1995) suggest that government directs the money which utilities collect from their customers for utility-sponsored energy conservation to a central fund and makes it available to everybody involved in demand-side bidding. They argue that this would result in competition between utilities, consultancy firms and users surrounding the delivery of the best and cheapest energy conservation.

2.3 Private energy service companies

ESCOs are private concerns that aim to overcome a number of market and institutional barriers which inhibit direct customer or utility investment in improved end-use energy efficiency. They offer an integrated service that provides capabilities that energy users often do not possess. Levine et al (1992) identify these services offered by ESCOs as the following:

- they provide engineering and managerial skills to help end-users to assess and implement optimal energy efficiency improvements;
- they assume the technical, financial and operational risks associated with implementing energy efficiency improvements, by entering into contracts with end-users whereby the fee that they receive is proportional to the savings achieved over long periods of time and savings are usually guaranteed. If no savings are attained, there is no payment[5]; and
- they arrange project financing.

The ESCO is in many ways the DSM counterpart to the independent power producers and represents a way of tapping into the market for energy-efficient products and services. Some ESCO projects, however, are contracted for, or supported by, utilities.

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[4] *Demand-side bidding* involves the use of outside contractors to achieve utility-assigned DSM quotas. Energy service companies (ESCOs), installation contractors, material suppliers, customers and other utilities are all potential bidders vying to provide these energy-efficiency services (Pye 1994). A competitive purchasing process is used to set the payments for these energy services and the DSM quota is awarded to the lowest bidders.

[5] This process whereby the ESCO guarantees the performance of the energy efficiency improvements, eliminating the risk for the owner and getting a return on its investment through profit-sharing, is referred to as *performance contracting* (IIEC 1992).

An example of an ESCO is INTESCO (the International Energy Services Company) which finances energy efficiency investments using a shared-savings approach. The ESCO aims to overcome the constraints of capital availability which limit the efforts of utilities, governments and end-users to invest in energy-efficient products, equipment and technologies. The ESCO assumes the up-front financial risk in implementing energy efficiency improvements and their fees are contingent on successful performance. By entering into contracts with utilities and using this shared-savings approach, end-users obtain energy and bill savings without investing any of their own capital, and the utility benefits from the energy savings achieved and pays only for demonstrated savings (SRC 1994).

The capacity for ESCOs to deliver DSM has not been well documented, but some conclusions have been drawn from the experience in the United States. It has been argued that where ESCOs are left to their own devices, most choose to concentrate on the largest customers and the most lucrative energy-saving measures, particularly lighting and co-generation[6] (Nadel 1991). Where ESCOs are contracted by utilities to provide energy services to their customers at rates close to the equivalent of the avoided costs for utilities, they can provide many measures to the end-users at no cost and still make a profit. In the United States, ESCOs have made a significant contribution to energy efficiency, but most of the ESCO projects occurring without utility support have been implemented in the institutional sector (schools, hospitals and government) and the commercial sector. They have had a minimal impact on the residential and industrial sectors which account for over two-thirds of electricity use in the country (Geller et al 1995).

In France, ESCOs have demonstrated their success. These ESCOs focus on energy management rather than on financial assistance, and are staffed primarily by engineers and technicians rather than financial analysts (as in the United States). The French ESCOs are responsible for ongoing maintenance and operation of the facilities they serve. They differ from the American ESCOs in that they are often paid a fixed fee, rather than entering into contracts for profit sharing (Nadel et al n.d.).

ESCOs have been considered as an option in a number of developing countries, such as India and Thailand. These ESCOs have targeted the industrial sector and their strategies have met with varying degrees of success (IIEC 1992; SRC 1994). It appears that, in developing countries, financial constraints often impede the success of ESCOs, as was the case in Thailand (IIEC 1992).

2.4 Conclusion

Jackson (1992) states that an evaluation of the weaknesses and strengths of the different sets of institutions - government, utilities and third-party companies - leads to the conclusion that there is a need for coordinated action between these three different sectors. In this way, one can optimise the structures of energy supply so as to provide least-cost energy services which reduce energy consumption. The roles that government should take on are to stimulate the development of energy efficiency equipment through the funding of research and development, and to stimulate the penetration of energy efficiency technology on the market in its capacity as a big purchaser (Olerup 1995). Furthermore, government can facilitate utility and end-user involvement by removing disincentives such as low energy prices and by delinking electricity sales and utility profits. Under the right regulatory conditions, utilities have a significant role to play in demand-side management activities. Utilities have a direct relationship with the end-user, placing them in a unique position to offer and promote energy-efficient strategies and financial packages to their customers. ESCOs have the potential to offer support to both utilities and end-users, providing skills, arranging financing and absorbing risk, thus helping to overcome barriers of entry into the energy-efficiency market.

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[6] This action of installing only the lowest cost or easy-to-install DSM measures, while ignoring other cost-effective opportunities, is referred to as *cream skimming* (Pye 1994).

3. Why adopt end-use energy efficiency?

The motivations for adopting end-use energy efficiency vary between institutions, but some common ground does exist. The emphasis placed on the different motivations also varies between countries and is dependent on the political priorities of the government which may, in turn, be influenced by the socio-economic status of the end-users. For example, in the United States concerns for the environment and energy security are the main motivations behind energy efficiency programmes, while in Thailand equity and economic development are the primary motivations.

3.1 Economic motivations

Expenditure on fuels consumes a substantial portion of a poor household's income. From relationships between income and payments for energy services, it has been established that the lower the income, the higher the proportion of income spent on energy services (Thorne 1995). If end-use efficiency is increased, thereby reducing the energy bills of the consumer, a portion of consumer income will be released for other purchases (Nadel et al n.d.).

On a macro-economic level, the loss in international competitiveness which results from using energy and electricity less efficiently than other countries is a concern. For example, Japan and West Germany[7] are increasing their energy efficiency at a faster pace than the United States and could establish a competitive advantage over the United States (Moskowitz et al n.d.). This is also considered to be a significant issue for developing economies, because the worldwide production and use of energy-efficient equipment is increasing and, if developing countries do not follow suit, they could become burdened with outdated products and factories, thereby reducing their international competitiveness (Nadel et al n.d.).

End-use energy efficiency is also presented as a means of meeting debt service repayments. In Brazil, for example, the dramatic increase in electricity consumption between 1970 and 1988, and the forecast of a further doubling of consumption between 1988 and 2000, resulted in the utilities investing $75 billion in new generation, transmission and distribution facilities between 1970 and 1987 (Levine et al 1992). Pursuing this supply-oriented strategy contributed to the country incurring high debt service requirements, while still having insufficient revenues to meet the projected demand. Therefore, the government instituted an end-use electricity efficiency programme to slow down the pattern of electricity consumption in order to reduce energy-related debt (De Araújo et al n.d.).

In developing countries, studies that have projected energy demand have predicted large increases in future demand. These studies conclude that a continuing increase in energy use is a prerequisite to progress and economic development in developing countries, but that limited materials and capital resources are likely to inhibit the attainment of high energy growth rates and, therefore, economic development will be unattainable for these people. Pursuing a supply-side energy strategy incurs high costs in terms of investment. Even if supply efficiency were improved, the capital requirement for future expansion of generating capacity is seldom available (Dutt n.d.). DSM programmes of improving end-use efficiency can provide a solution to this problem. By improving the efficiency of production and end-use, demand for electricity and for generation capacity can be reduced. Thus, electricity conservation can potentially lead to greater productivity and economic growth.

When weighing up the costs and benefits of DSM programmes versus supply-oriented programmes, the savings involved in end-use efficiency are clearly evident. Nadel et al (n.d.) quantify these savings, concluding that the costs of supplying new hydro-electric and fossil fuel

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[7] This is despite the fact that the price of energy is much higher in Japan and Germany than in the United States and, therefore, they need to increase efficiency.

facilities outweigh the costs of increasing end-use efficiency. Increasing end-use efficiency typically costs \$300-\$1 000 per kW saved as compared to \$1 500-\$3 000 per kW supplied for new hydro-electric and fossil fuel facilities. Furthermore, in developing countries, there is great potential for cost-effectively increasing the efficiency of electricity use. For example, in Brazil, conservation measures can reduce electricity consumption by 20% at only two-fifths the cost of new electricity supply.

There are a number of different tools for evaluating the costs and benefits associated with demand-side management programmes versus those associated with supply-oriented programmes. One such method is to compare the *costs of conserved energy* (CCE) and the *cost of avoided installed capacity* (CAPIC) to the long run marginal cost and the costs of new installed generating capacity. Another method to determine the costs and benefits from the perspective of the end user is to calculate the *life-cycle costs* of an appliance which meets a particular end-use. The life-cycle cost includes the actual amount paid for the asset, the present value of replacing that asset, the present value of operating that appliance and the present value of maintenance that would be required by the appliance (Thorne 1995).

3.2 Environmental motivations

Environmental effects of energy generation manifest themselves at a number of different scales - household, local, national and global. Micro-environmental pollution results from the burning of fuels within the household. The undesirable by-products of combustion, such as carbon monoxide, water vapour, nitrogen oxide, sulphur-dioxide and particulates, have negative effects on the health of the occupants of these households (Thorne 1995). These negative effects could be decreased if fuels were consumed more efficiently, if less polluting energy sources were employed and/or if energy end-use was reduced through thermal performance improvements of the dwelling structure. At the national level, adverse environmental impacts of increasing energy generating capacity include the disruption of local settlements, land degradation and increased air and water pollution (Nadel et al n.d.). By slowing the pace of power plant construction, these adverse environmental impacts can be reduced or avoided. There is increasing concern for the global environment which is based on, amongst others, the threat of climate change resulting from the enhanced greenhouse effect. The United Nations Intergovernmental Panel on Climate Change (IPCC), consisting of 300 of the world's leading climate scientists, has stated that carbon dioxide is responsible for an estimated 60% of the enhanced greenhouse effect (Greenpeace 1993a). Using less energy, and thereby burning less fossil fuels, has been identified as the most effective means of reducing carbon dioxide emissions in the near future.

Energy efficiency has gained increasing attention as a means of meeting global environmental commitments as set out by the Framework Convention on Climate Change (FCCC). The FCCC had, by 5 June 1995, 135 Parties, including the European Economic Community (Climate Change Bulletin 1995). In European countries, the justification for energy efficiency policies is, therefore, less related to energy policy (such as to alleviate the import bill and/or oil dependency) and more related to environmental policy concerns for the greenhouse effect and the need for abatement strategies (Lapillonne 1993).

Both Norway and Sweden presently rely on non-fossil fuel sources (hydro in Norway and nuclear in Sweden). As demand increases, Norway is faced with a problem of increasingly needing to use non-renewable fuels for energy generation (Schipper and Hawk 1991). Its energy conservation programme has, therefore, grown out of a concern for the environment, specifically issues of global warming and ozone depletion, and out of concern for the increasing marginal cost of electricity generation as it becomes more and more difficult to find additional sources of energy to meet growing demand. Sweden, on the other hand, is, out of environmental concern, decommissioning its nuclear power stations and is looking to wind, imports and DSM to take up the slack.

3.3 Security motivations

Reliance on imported oil and gas is often considered a national economic security risk, especially after the oil shocks of the 1970s, and energy efficiency strategies are considered important in this regard. In other words, by decreasing energy use, the consumption of oil and gas is decreased. It follows that the economic risks with regards to importing oil and gas decrease (Moskowitz et al n.d.).

Fuel security is also a concern at the household level where there are diminishing stocks of fuelwood and coal. Energy efficiency programmes have been adopted to encourage the sustainable use of these fuels and to promote the adoption of more efficient technologies and fuels which will reduce the local dependence on these fuels.

3.4 Equity motivations

Equity is concerned with equality of access to energy services. Equity of energy provision is not only concerned with physical access to a range of fuels and appliances which provide energy services, but also with real access to those services. Real access combines physical access with affordability of services. The urban poor often pay more for their less efficient, inappropriate and hazardous fuels than they would if they were using electricity. Thorne (1995: 12) highlights the importance of this issue, identifying the need to 'electrify efficiently and disseminate efficient appliances in order to widen the access to possibilities of energy and financial savings'.

While end-use efficiency programmes are often motivated for on the basis that they reduce the need for additional generating capacity, it has been argued that, among the poor, energy efficiency results in a greater demand for fuels, rather than a reduction in consumption. The micro-economic theory of consumer 'take-back' states that end-users respond to reductions in their monthly energy bills by increasing consumption in other ways up to the point of economic indifference. The level of lost savings is related to the household's price elasticity of demand for electricity (Parker 1991). Therefore, for the poor, who experience low levels of services, energy efficiency offers an opportunity to meet their energy needs and raise their standards of living (Thorne 1995). Energy efficiency improvements can thus be motivated for on equity grounds, where they allow more energy to be used for the same amount of money, thereby alleviating energy poverty (Thorne 1995).

Gibbons et al (1989) call for a reconciliation between energy efficiency, environmental concerns and economic development. They argue that the most promising opportunities for developing countries to sustain economic development without incurring the costs of fossil-fuel use, lies in the employment of energy efficiency strategies.

4. Barriers to implementation

There exist a number of financial, economic, behavioural, technological and policy barriers to the implementation of measures to increase end-use energy efficiency. The conservation programmes and strategies in place in other countries are predominantly aimed at overcoming these barriers and enabling an end-use oriented approach to the provision of energy services. The most common barriers are identified and discussed below and those strategies and programmes which have been employed or proposed to overcome these barriers are briefly alluded to. These strategies and programmes are discussed in more detail in Chapter Four.

4.1 Availability of technology

The lack of energy efficiency products on the market limits the possibilities for conservation. Many energy-efficient products available internationally are not yet manufactured in developing countries (Batra et al 1993). Problems related to this are:

- a lack of understanding of the techniques and equipment available for more energy-efficient use;
- a lack of consumer demand, which in turn is partly determined by the absence of strong environmental lobby groups;
- insufficient quantities of adequately trained individuals to train personnel in the operation and maintenance of new technology;
- a lack of proven technology to solve specific problems in the developing country context;
- insufficient local technological capacity to develop energy-efficient appliances and equipment (such a paucity in technological capacity is linked to inadequate access to finance for research and development, and demonstration);
- overpriced, imported technologies;[8] and
- scarcity of spare parts for imported equipment.

Energy-efficient products may not be manufactured indigenously because manufacturers are not aware of them, cannot obtain rights to manufacture them, or do not perceive a market for the product, as individual end-users tend to purchase less expensive, less efficient products (Levine et al 1992).

Strategies to overcome these barriers are to implement R & D programmes, for example testing and domestic development of new technologies, efficiency awards and public demonstration programmes showing energy-efficient technologies. There is also the example in Thailand of a proposal to drop the import levy on equipment which is used to produce energy-efficient equipment to 5% of the stated value (Parker 1991). There is also a proposal to drop the levy not only on the production equipment, but also on imported energy efficiency products, where there is not a similarly efficient product being manufactured domestically, although there is a potential problem in defining 'energy-efficient' products. Furthermore, the list of approved energy efficiency materials and equipment which can be assessed at a lower duty as importers petition for classification of their products under this heading, will need continual updating.

4.2 Lack of information

Lack of information is commonly cited as a barrier to adopting energy conservation measures and to adopting technologies that would lead to more efficient use of energy. More specifically, imperfect information is considered to be a barrier to market-based solutions as the efficient working of the market is dependent on there being adequate information (Batra et al 1993).

Most energy decision-makers, such as consumers, architects, developers, designers and builders, are not aware of the range of energy-efficient products they can use to reduce the energy consumption and demand of their buildings. They lack current and credible information on the latest conservation technology and they may not trust the energy conservation companies to deliver such information because of the perceived conflict of interest (Levine et al 1992). Where they are aware of the advantages of energy-efficient equipment, they might still not install it owing to the fact that they are unaware of how to specify, install or maintain the equipment (IIEC 1994a).

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[8] Where appropriate energy-efficient technologies are not available domestically, it becomes necessary to import these technologies. Import duties do not distinguish between energy-efficient and ordinary equipment and can sometimes price the technology out of the market. In Thailand, for example, current duties and taxes on imports vary from 30% to 60% of their stated value (Parker 1991). This can increase the cost of imported energy saving technologies to such an extent that they are no longer cost effective.

This also applies to consumers who usually face high transaction costs in obtaining timely, credible and relevant information when purchasing major energy appliances or making decisions on competing consuming or conserving options (Sioshansi 1991). There is a general lack of awareness surrounding the performance, savings and availability of more efficient technologies (Parker 1991). This makes it difficult for some consumers to choose between a high capital cost and a low operating cost option.

Furthermore, end-users often lack information regarding their current electricity consumption because their bills are not disaggregated so that monthly consumption levels and trends can be monitored (Levine et al 1992).

Without the help of established, reputable energy consultants (who do not exist in many parts of the world), building purchasers have no credible way of comparing the energy cost of different buildings.

Solutions to this lack of information include consumer education programmes such as appliance labelling and performance testing, information programmes, equipment demonstrations, free energy audits and government procurement linked to independent and performance contracting testing.

4.3 First-cost sensitivity

Even though they save money in the long run, energy-efficient products tend to have a higher up-front cost than their inefficient counterparts. Many purchasing decisions are made on an up-front cost basis, which puts energy efficiency at a disadvantage (IIEC 1994a). End-users, especially lower-income target groups, tend to be extremely sensitive to first costs and, where payback periods are too long, they are unlikely to make the investment in the energy-efficient technology. The required payback period of the end-user is too short to merit serious consideration of retrofit measures that do not pay for themselves over six months to three years (Sioshansi 1991). Measures which pay for themselves over several years will require government or utility incentives to span the financial gap. Where the end-user can perceive that he/she is saving energy and/or money, demand-side management measures are easier to implement (Parker 1991). Comprehensive billing and metering is an important measure to make the end-user more aware of savings.

Incentive programmes can include utility sponsored rebate programmes to encourage the purchase of more efficient appliances, or tax credits for equipment that is identified as providing cost-effective savings but whose first cost tends to inhibit end-users from considering installation. Other options include direct installation by the utilities, banks or ESCOs who pay for some or all of the associated incremental costs, and tariffs as disincentives, designed to discourage consumer decisions that waste energy or utilise it inefficiently.

4.4 Split incentives

Split incentives involve the separation of responsibilities for making capital investments and paying operating costs (Dutt n.d.). Developers and landlords select building designs and equipment, but it is the buyers and tenants who must pay the energy bills. This separation of purchasing and operating costs results in there being no incentive to select energy-efficient equipment (IIEC 1994a). Since the developer's prime motivation is to keep the rental fee or original purchase price low, they tend to invest in the lowest-capital cost options. Such motivations result in low efficiency housing stock and high operating costs which are borne by the renter/occupier over time (Sioshansi 1991). The need for developers to keep the rental fee or original purchase price low will be even greater for the development of low-income housing and, therefore, these houses are likely to be very energy-inefficient. Performance contracting procedures are a means of overcoming this problem.

4.5 Price distortions

Energy prices do not fully reflect the environmental, security-related and social costs associated with energy production and use. They tend only to reflect the private costs of production and often even these are not reflected fully. The reason for this is that electricity and fuel prices are normally based on average rather than marginal costs. In some cases, the average cost is less than the full marginal cost of expanding power supply options and, therefore, electricity prices will be too low (Geller 1991). Average cost pricing and the failure to incorporate externalities into energy prices contributes to underinvestment in energy efficiency. In developing countries, energy prices have been viewed in a segmented manner dominated by social considerations which have been perceived to be in conflict with other pricing objectives (Batra et al 1993). This has often resulted in the subsidisation of electric utility capital or operating costs (Parker 1991). For example, 60% of the cost of electricity is subsidised in Pakistan and 20% in India. These subsidies represent barriers to the adoption of energy efficiency because they encourage excessive consumption, resource depletion and environmental pollution and they result in loss in efficiency for society (Levine et al 1992).

When electricity prices do not vary with time or pattern of use, some customers will face prices that are substantially below the true cost of service received, while others will pay rates that are above. The effect of these price distortions is two-fold: firstly, current electricity prices tend to be lower than they ought to be, making electricity consumption cheap relative to conservation and, secondly, time-invariant prices result in too much consumption during peak periods and too little during off-peak periods (Sioshansi 1991).

Where electricity is price elastic, end-users respond to changes in price. The fact that end-users respond to rising prices to some degree underscores the importance of ensuring that electricity prices reflect the full cost of power production (Moskowitz et al n.d.).

Electricity should, theoretically, be priced to reflect the long-run marginal costs of production. Proper electricity prices would encourage efficiency, reduce consumption and stabilise supply. In the short term, increasing electricity prices to reflect direct costs and environmental costs would disadvantage low-income end-users. Thus, while there may be significant long-run benefits of having electricity prices reflect full costs, achieving this outcome presents considerable transitional and distributional problems. To mitigate these problems, rate increases can be phased in slowly, and price structures can be altered to include low 'lifeline' rates for a 'subsistence' amount of electricity use, with higher rates for electricity use above the lifeline allotment (Levine et al 1992). Furthermore, time-of-use rates are important measures to reflect the real costs of production, generation and distribution of energy which varies over time.

4.6 Finance

The removal of many barriers, such as lack of information and the lack of advanced technology, depends on adequate finances and credit availability. In developing countries, the introduction of energy efficiency technologies, policies and programmes are often limited by financial constraints. This occurs in a number of different sectors - households, government and private utility sector. At the household level, financial constraints are experienced because low-income households are incapable of meeting the up-front capital costs involved in purchasing energy-efficient equipment and making energy efficiency improvements. At the level of government, misallocation and lack of government funds result in the state's incapability of financing energy-efficient programmes and this, therefore, limits the type of energy efficiency programmes that they initiate to low-cost programmes. In the private sector, regulations result in insufficient economic incentives to implement energy-efficient programmes and often encourage private utilities to pursue profit through increased sales revenues.

One of the major barriers to implementing end-use efficiency programmes is the lack of funding. The main reason for this is that international assistance institutions such as the multilateral

World Bank, the regional development banks (for example, the Asian Development Bank, the Inter-American Development Bank and the African Development Bank), the United Nations Development Programme and the bilateral US Agency for International Development have historically favoured the delivery of bulk energy, especially electricity, over the delivery of energy services (Levine et al 1992). The reason for this is that there is pressure within the multilateral development banks to meet annual lending targets, militating against small loans like those generally involved in energy efficiency projects (Philips 1991).

There has, however, been a shift toward international financial institutions playing an important role in financing energy efficiency projects in developing countries. An example of the financing of such a project is the Programme for Acceleration of Commercial Energy Research (PACER) in India, which was financed by US Aid. PACER channels United States funds to energy efficiency programmes and aims to promote development of technology through financial assistance to manufacturers, research institutions and end-users. To be eligible as a recipient of these funds the programme must fulfil the criterion of developing new or innovative products or processes with a significant potential for commercialisation within five years (Batra et al 1993).

4.7 Weak incentives

In some cases, energy represents a small fraction of the total cost of owning and operating a household. These low relative costs along with competing demands on decision-makers' time, limit consideration of energy-efficient options by these households (Geller 1991). This does not generally hold true in the case of the poor, where the costs of energy consumption represent a large proportion of their incomes.

Under most current pricing regimes, electric power companies have little or no compelling economic incentives to invest in energy conservation. Energy efficiency reduces sales and, therefore, most utilities would lose revenues in excess of any savings derived from lower fuel and operating costs. This would apply to most utilities whose marginal cost of generation is far below their average rates (Sioshansi 1991).

4.8 Government policy and regulation

If cost-effective measures conflict with existing regulatory mechanisms, the implementation of these energy efficiency improvements will be difficult (Batra et al 1993). Taxation policies can provide disincentives to the adoption of energy-efficient products that are cost-effective from a social perspective. Excise and import duties can raise the retail price of energy-efficient products beyond that which is cost-effective and, therefore, it is important to remove disincentives to energy efficiency.

Government spending, tax and regulatory policies are strongly tilted in favour of energy production as opposed to greater energy efficiency. For example, in the United States, 90% of the federal government's R&D budget is devoted to supply options, while at the state level, regulation usually makes it more profitable to promote consumption than energy conservation (Geller 1991).

4.9 Institutional

Increased end-use energy efficiency may be hindered by the lack of adequate institutional capability. The lack of local and national institutions and agencies that produce, gather and disseminate information, distribute financial resources, design and monitor programmes and policies and train personnel can limit adoption of end-use efficiency technologies. Developing countries are often faced with a shortage of efficiency-oriented managers and performance-oriented staff, basic limitations in the technical capabilities of staff, weak linkages with both government and industry, limited financial resources and a dependence on external initiatives and resources in defining and implementing new directions for technology choices. A strong indigenous institutional capability is essential to the promotion of improvements in electricity efficiency. The lack of adequate institutional capability in many developing countries discourages international assistance institutions from funding small innovative technologies or programmes because organisations to administer and monitor the programmes either do not exist or are not able to provide the needed services (Levine et al 1992). On the other hand, many multi- and bi-lateral funding agencies require that their projects are led by foreign consultants. This results in projects being completed without impacting on institutional capacity building.

Energy-efficient technologies

1. Introduction

While it is essential that technology does not lead energy efficiency investment and development, integrated energy planning (IEP) should consider, among other strategies and policies, energy-efficient technologies as a means of meeting household energy needs effectively. An end-use-oriented energy-planning perspective could be engaged to identify household energy uses and to select the best means of meeting those needs. Energy-efficient technologies should be appropriately employed to reduce the most consumptive household end-uses. This chapter looks at the different energy-efficient technologies available to reduce household energy consumption, thereby improving equity of access to energy and other services and reducing environmental and health impacts of electricity generation. The two areas discussed are thermally efficient houses and energy-efficient appliances.

2. Passive thermal control

2.1 Introduction

> Climatic design is the one approach by which to reduce the energy cost of a building comprehensively: the building design is first line of defence against the stress of outside climate (Watson 1983: 3).

Internationally, there has been a move away from using traditional architecture and materials, which were designed to capture the benefits of passive solar control. Modern architecture has tended to ignore these principles inherent in the old designs and, as a result, requires artificial heating and/or cooling to achieve desired levels of thermal comfort. This results in most modern buildings consuming huge amounts of energy for cooling, heating and lighting. Careful attention to layout, materials and insulation could reduce the waste of energy significantly. The construction of energy-efficient buildings may sometimes be more expensive, but low-energy buildings quickly pay for themselves. Furthermore, low-energy buildings reduce the costs of energy for the occupants and, therefore, free money for other uses. The aim of climatic design is to reach mutually satisfactory results in *human comfort* and *energy efficiency*, by designing the building to suit its local climate. Many climatic design techniques can reduce both heating and cooling energy costs. These techniques are discussed below.

2.2 Principles of passive thermal design

Solar radiation affects buildings in two ways:

- entering the building through windows and being absorbed by surfaces within the building, it causes a heating effect; and
- being absorbed by outside surfaces of the building it creates a heat input into the fabric which will partly be conducted through the fabric and subsequently emitted to the inside.

Both these effects can be influenced by the designer. The transmission of solar radiation through windows is determined by:

- orientation of the window;
- size of the window;

- type of glazing; and
- shading devices, either external or internal.

The rate of heat flow through solid walls and roofs is determined by:

- the orientation of the surface and, therefore, the intensity of solar radiation on it;
- the area of the exposed surface;
- the absorption coefficient of the surface;
- the surface conductance, governing the heat emission; and
- the thermal capacity of the walls, which is dependent on the thickness and insulation properties of walls (Szokolay 1977).

Passive solar principles can be utilised in building design to either exclude or include solar radiation. Furthermore, it is possible to design houses so that they retain heat during the cold months and exclude heat during the warmer months. These measures need not be costly, especially if they are included in the design at the time of construction.

The thermal performance of the dwelling structure can be manipulated by employing measures which pertain to either the planning of the site or the building envelope.[1] The planning of the site involves using windbreaks, plants and water, indoor and outdoor rooms and earth sheltering. The thermal control of the dwelling through the manipulation of the building envelope involves the employment of solar walls and windows, the thermal envelope, sun shading and natural ventilation (Watson 1983).

2.2.1 *Landscaping*

The use of landscaping to shade a house is a simple and cost-effective means of reducing energy consumption, while maintaining interior comfort levels. Trees are, however, commonly cleared away before construction occurs and no landscape is installed in their place.

Planting can have both shading and insulation effects. A perennial climbing ivy or tree has the potential to shade the house and, therefore, reduce the amount of solar radiation reaching the interior. This will shade the house in summer, but lose its leaves in winter and, therefore, allow the transmittance of heat into the house in winter. Evergreen ivy can also serve as an insulation barrier, preventing convective heat loss during the winter months. It is essential that one takes into consideration which walls receive solar radiation during the hot and cold months and plant accordingly (Watson 1983).

Such measures have proved to reduce peak electrical demand. For example, in Thailand, shading has shown to substantially increase interior comfort levels while cutting space cooling peak electrical demand by over 50% (Parker 1991).

2.2.2 *Building shape and orientation*

Orientating the building to take advantage of solar radiation is a simple method of conserving energy, which requires knowledge of sun-paths. The winter sun-path is much shorter and lower than the summer sun-path. Designing with knowledge of these paths, and the radiation incident

[1] The building envelope is a device through which heat exchange between interior and exterior environments is controlled (Watson 1983). The fundamental control options are to admit or exclude heat gain from external energy sources and to contain or release heat energy present in the interior.

at any point in time, enables the building to capture the sun in a way which maximises solar radiation when most needed and minimises solar radiation when overheating occurs (Watson 1983).

The shape and orientation of the building can be designed to maximise exposure to winter sun, minimise winter wind turbulence, to minimise exposure to summer sun and to maximise exposure to summer breezes. Variations in shape affect the amount of exterior surface area for a given volume enclosed, thus affecting the solar loss/gain and determining the need for different thermal considerations. Residential buildings tend to have large surface-area-to-volume ratios and small internal loads and, therefore, their energy use is dominated by the external environment and characteristics of the building shell. A study of surface-area-to-volume ratios indicates that elongation along the east-west direction is optimal in all climates. The amount of elongation needed depends on the climate. In cool and hot-dry climates, a compact building form exposing minimal surface area to a harsh environment is desirable. In hot and humid climates, buildings should be elongated liberally in an east-west direction because of the intense summer solar radiation on the east and west sides (Hirst et al 1986).

2.2.3 *Shading devices*

External shading devices are the most efficient measures of solar control (Szokolay 1977). These devices can be tailored to specific latitudes, local heating and cooling seasons and varying orientations (Watson 1983). Almanacs and sun path diagrams are used to find the position of the sun at any point in time. By this means, shadow angles can be obtained to predict the performance of a shading device in terms of omitting or allowing the penetration of sun at any given time or to predict the overshadowing effect of other buildings or objects (Szokolay 1977).

Many different devices can have the same performance. Thus, eaves, awnings, louvres and blinds can be used to achieve the same end. Fixed shading devices, such as overhangs, are purely negative controls, excluding solar radiation. Fixed devices can, however, be designed to give selective performance, admitting the sun when it is desirable and excluding it when it would cause overheating (Szokolay 1977). For example, because the sun angles are different in summer than in winter, wide overhanging eaves can be used to exclude the high altitude summer sun, but admit radiation in winter when the sun is at a low angle. Thus, the concept of providing sun shading does not need to conflict with winter solar design concepts.

2.2.4 *Thermal capacity of the building*

The *thermal mass* of the building fabric can moderate diurnal temperature fluctuations within the building envelope. Solar gain occurs during the day and is lost at night. If the heat can be stored in the massive building fabric, it can be preserved for use during the cold night period (Szokolay 1977). Materials with high thermal capacitance should thus be located wherever surfaces are exposed to direct winter solar radiation for extended periods of time (Watson 1983). Heat capacity alone, however, does not necessarily indicate a good heat storage medium. The thermal admittance of the material is the most important property.[2] Insulation on the outside of the thermal mass ensures that heat stored in the thermal mass during the day is transferred to the inside of the building envelope at night (Szokolay 1977).

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[2]*Thermal admittance* is the property which indicates the quality of the material as a heat storer. The overall performance of the material is determined by its conductivity as well as its heat capacity. Materials of high thermal admittance are quick to absorb heat to which they are exposed and are also quick to lose the heat which they retain (Watson 1983).

2.2.5 *Reflective materials*
The use of reflective materials on surfaces orientated toward the summer sun can help to keep the building cooler in summer, by reflecting the solar radiation and, therefore, reducing the amount of heat absorbed by the building walls and transmitted to the interior (Watson 1983).

2.3 Residential new construction[3]
It is much cheaper and simpler to install conservation measures while a house is being built than to retrofit these measures later. While a house is being built, conservation measures can be installed for only the incremental cost beyond present construction practices. New construction conservation opportunities are often referred to as 'lost-opportunity' resources, because if the conservation measures are not installed at the time of construction, then those opportunities may be forgone.

Residential new-construction programmes range widely from simple information programmes to comprehensive programmes that include education, codes and standards, technical training and financial incentives.

There is a lot of experience in this field in the United States. Residential new construction programmes have usually consisted of the utility specifying performance or prescriptive standards for an energy-efficient houses, certifying new houses that are in compliance with its standards and promoting the advantages of certified houses to potential homebuyers through, for example, the media, mortgage lenders and cooperative advertising with builders. Some utilities have gone further to provide rebates or rate reductions to builders or homebuyers, to train builders on how to sell an energy-efficient home and to arrange for higher loan limits for certified efficient homes. The standards for what comprises an energy-efficient house vary widely between utilities. Programmes that target high savings per house usually include financial incentives and extensive training programmes.

Participation in residential new construction programmes has varied widely in the United States. Programmes with higher participation rates tend to target a smaller number of end-users and seek lower energy savings in the homes. Higher participation rates have also been experienced where utilities have sought to educate consumers about the economic and thermal comfort benefits of such conservation measures. Furthermore, the more successful programmes have typically emphasised personal, direct marketing and have sought to enlist the builders in the early stages of planning a project.

Nadel (1991) suggests that programme success can, therefore, be attributed to:

- intervening early in the design and planning process;
- including education, training, design assistance and quality control activities;
- targeting specific groups of end-users;
- obtaining the active support of builders by involving them in the programme planning process and providing flexible programme procedures that facilitate builder participation; and
- actively marketing the programme to end-users so that a demand is created for energy-efficient homes.

Thailand offers another example where architectural considerations and solar control have become part of a DSM proposal. Traditional houses were designed to promote natural ventilation and cooling and their locations commonly took advantage of shading from the

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[3] This section on residential new construction programmes is based predominantly on the work of Nadel (1991).

tropical landscape, while their orientation took into account the daily arc of the sun's path. Modern Thai houses reflect little of the traditional wisdom found in the old designs. They are seldom designed to consider ventilation and rely on artificial cooling systems. Indigenous trees and plants are commonly cleared from the site so that almost no site shading is available. A variety of low-cost measures were identified as a means to reduce energy consumption associated with cooling in Thai houses, while retaining the thermal comfort of the structure at desirable levels. These measures include the architectural design of the building (such as orientation of building, size and orientation of windows, thermal mass, shadowing devices and earth cooling), landscaping, and simple low-cost measures such as insulation, radiant barriers, reflective paints and reflective windows. To promote and encourage the adoption of these measures in new residential housing, an energy building code was suggested. This code will require insulation or a radiant barrier to be installed in the roof of all new residential structures and the use of passive solar design principles, such as shading through overhangs, to be part of new designs. It is expected that such a code will substantially reduce cooling needs in Thailand's future residential building stock (Parker 1991).

2.4 Existing houses

Even if thermal regulations were instituted for new houses now, the present housing stock would still form the larger proportion of the projected housing stock in the near future. Retrofitting of houses built prior to the institution of thermal regulations for new houses will, therefore, effect larger energy savings although the cost will be higher. For example, in France, 75% of existing houses were built prior to 1974 when thermal regulations for new housing were first promulgated. A housing policy has therefore been implemented to effect improvements in those houses built prior to the thermal regulations. This policy includes three main types of action:

- energy decision-making aids;
- regulation and standardisation of components; and
- investment aids, via direct subsidies or fiscal deductions (Ademe 1995).

In the United States, low-income weatherisation programmes have been introduced to ease the burden of energy costs on low-income households. These programmes have been implemented by both government and utilities.[4]

Initial programmes, funded by the Department of Energy (DoE) and other federal agencies, gave priority to weatherising the residences of the elderly and the disabled. Rental units could be eligible for funding if the benefits accrued to the tenant rather than the landlord and specifically rents could not be raised on the basis of improvements resulting from the weatherisation. This was later adjusted to include those individuals who fell on or beneath the poverty level, and further adjusted twice to increase the income limit for programme eligibility to 125% of the poverty level and then again to 150% of the poverty level. Two million households were weatherised under the DoE programme between 1974 and 1989. Annual energy savings from these programmes have been estimated as between 6 and 10% of individual household energy.

A common source of credit for low-income groups in the United States is their utility bill, since winter shut-offs are prohibited and extended payments are often provided. The provision of this credit can result in bad debts for utilities and, therefore, the gas and electric utilities have been motivated to engage in low-income weatherisation programmes so as to reduce these debts and potentially address the low-income bill-payment problem. The types of measures installed by

[4] This section on low-income weatherisation programmes in the United States is taken from Schlegel et al (1991).

utility programmes have varied significantly from low cost measures such as water heater insulation and weather stripping[5] to attic and wall insulation. Annual energy savings for gas-heated homes have been estimated as ranging between 6% and 23% of individual household energy.

3. Energy-efficient appliances

3.1 Cooking, water heating and space-heating/cooling

A number of different energy sources are used to satisfy the end-uses of cooking, water-heating and space-heating or -cooling. The fuel used to meet these energy needs varies substantially between industrialised and developing countries, and between lower and higher income households within developing countries. In industrialised countries, these end-uses of cooking, water-heating and space-heating/cooling are met by 'modern' fuels, such as gas and electricity. Different appliances are employed to meet each end-use - stoves for cooking, electrical or gas water-heaters for heating water and electrical or gas heaters and electrical air conditioners for heating or cooling of space. In developing countries, the fuels utilised to meet these needs vary substantially in relation to household income, and cost and availability of different fuels. There is a tendency for lower income households to rely on 'traditional' biomass fuels to meet the multiple end-uses of cooking, water heating and space heating.

In developing country households, the majority of energy usage tends to be channelled toward the intertwined activities of cooking, water heating and space heating or cooling (Sathaye & Tyler 1991). The amount of energy devoted to each activity is climatically dependent.

3.1.1 Cooking and space heating

Cooking and space heating are addressed simultaneously in this section because space heating is a by-product of cooking, especially in low-income households where wood fuels and coal are used for cooking.

In developing countries, a single source of energy is often used to perform both cooking and space heating activities. In addition, a range of other services, such as lighting, water heating and social focus may be provided by a stove or fire. Despite increasing access to electricity as an energy source, cooking and space-heating continues to be met through alternative energy sources. There are a number of reasons for this:

- electric cookers are often incapable of providing the correct facilities for traditional meals (Dutt n.d.);
- cooking and space-heating requirements can be met simultaneously through the use of alternative fuels;[6]
- capital costs may inhibit the purchase of electric cookers and heaters; and
- operating costs of electric cookers and especially heaters may be substantially greater than those of alternative energy sources.

When looking at the efficiency of cooking, one needs to consider both the fuel and the appliance used in the delivery of the service. Although electricity and petroleum fuels are often more

[5] *Weather stripping* or *caulking* is the sealant applied between the sash and window frame to eliminate leaky windows and frames through which heated or cooled air is lost (PG&E 1993b).

[6] The use of one energy source, for example a coal stove, to meet multiple end-uses can be the most cost-effective and energy-efficient method of meeting those energy needs (Williams 1994).

expensive for cooking than solid fuels, solid fuels are associated with problems of high levels of pollutants at the point of use (Thorne 1995). This is, in turn, associated with health risks, such as respiratory disease.

The efficiency of the appliance used has a profound impact on both the amount of fuel consumed and the health effects associated with using the fuel. Owing to the widespread use of biomass, coal and paraffin in developing countries, it is essential that end-use efficiency programmes in those countries focus on the 'traditional' fuels available and attempt to increase the efficiency of use of that fuel. For example, efficient wood- and charcoal-burning cookstoves have been disseminated as a means of reducing the amount of wood or charcoal burned for specific energy tasks and for decreasing the amount of pollutants released into the household atmosphere. While many such stove programmes have met with little success, such strategies continue to be of significance (Thorne 1995). Passive thermal design principles are also essential to the reduction of the need for active space heating.

3.1.2 *Space cooling*

In those industrialised and developing countries where the climate dictates a need for space cooling, there is an increasing dependence on artificial or mechanical cooling systems. In such countries as, for example, Thailand, air conditioners are a substantial contributor to household energy consumption. Programmes have been adopted to reduce the energy required for space cooling. These programmes consist of two strategies - improving the efficiency of air conditioners and reducing the need for active space cooling through the use of passive thermal design principles. Examples of both strategies can be found in the residential demand side management proposal for Thailand.

In Thailand, air conditioning is widely used in residential households. These air conditioners are usually turned on in the evening hours adding a significant load to the peak electrical demand period. Low-cost inefficient air conditioners dominate the Thai market and thus substantial savings can be made through retrofitting of air conditioners in existing houses (Parker 1991). New Thai houses are seldom built with insulation, while more than half of them are installed with air conditioning. A study by Chou (1988) found that added insulation could potentially reduce space cooling needs by up to 200% in developing countries in tropical climates. Insulation of new residential construction has thus been proposed as a means of reducing the need for actives space cooling and for downsizing of high efficiency air conditioners. Such a programme has already been implemented in Singapore where regulatory energy standards for new construction dictate the inclusion of building insulation (Parker 1991).

3.1.3 *Water heating*

Electricity suffers transmission losses and distribution losses on its way to residences and, therefore, to use this high quality energy source to heat water from 25°C to 60°C is thermodynamically a poor use of energy. In many industrialised countries, and in some developing countries, a fuel (such as natural gas or fuel oil) is burned in homes to heat water. This is thermodynamically not much better, but at least it avoids the capital cost of the power plant. In petroleum-poor developing countries, such as India, a water heating fuel is not available and, therefore, electricity is used to heat water (Dutt n.d.). In addition, heat losses occur during hot water storage. Water heating constitutes between 30% and 50% of the total household energy load, but much of this can be saved. It is a service which can easily be controlled because the use of hot water need not coincide with the heating of hot water (Thorne 1995).

There are alternatives to electric hot water storage heating that should be considered. These include:

- solar water heating;

- in-line gas or electric water heater geysers; and
- heat pump water heaters.

Solar water-heaters employ relatively simple materials to heat the water to the required 60°C. Solar water heating is a cost-effective way of heating water where solar radiation is sufficient and where the main draw-off of hot water is in the evenings. Solar water-heaters are ideally suited to areas which experience a winter dry period, because this is when most water heating is required and when the skies will be clear and the solar energy can be captured. Water-heating exclusively by solar sources may not deliver hot water at certain times of the day or for short periods of the year, but a combined solar/storage geyser/in-line heater would result in fuel conservation while maintaining the convenience of having hot water on demand (Thorne 1995).

There is wide dissemination of solar water-heaters in Israel, where they have become mandatory. The Israeli government offered grants to help with conversion costs, issued standards on the manufacture and installation of solar water-heaters and reduced taxes on them. Already, two out of three Israeli homes are equipped with solar water-heaters. Solar energy provides about 3% of Israel's primary energy needs, replacing about 300,000 tonnes of oil annually and avoiding the release of a million tonnes of CO_2 (Greenpeace 1993b).

In-line water-heaters use less energy than storage heaters though they draw higher loads for shorter periods. Energy is conserved because in-line heaters heat water on demand and close to the point of use resulting in minimal heat losses. In-line water-heaters can be gas or electrically based. Electrical in-line heating of water is limited to households with a three-phase electricity supply, while gas in-line heating is dependent on the availability and cost of gas as a fuel (Greenpeace 1993b).

Heat pump water heaters are over three times more efficient than ordinary electric resistance water heaters. In the United States, heat pump water heaters have been shown to be as effective as solar water heaters, but at considerably less cost. Nevertheless, their first costs inhibit their penetration into the market, specifically in countries where hot water is used in small quantities and payback periods for the heat pump water heaters are long (Dutt n.d.).

3.2 Residential lighting

Residential lighting programmes are the most common of the DSM activities carried out by electric utilities (Menanteau 1994). Lighting offers some of the most spectacular opportunities for electricity conservation (Dutt n.d.). The reasons for this are:

- lighting consumes 8-17% of total electricity produced in industrialised countries and the share in developing countries can be larger;
- energy use can be reduced by as much as 75% without reducing lighting levels - such a reduction is difficult to achieve in most other end uses;
- some uses of lighting coincide with peak electricity demand and, therefore, a reduction in energy use can alleviate the growing peak load; and
- lamps have a relatively short life compared to other capital equipment and, therefore, savings can be quickly realised through an implementation programme which capitalises on this high turnover rate (Dutt n.d.; Nadel 1991).

3.2.1 Incandescent lamps

Despite the fact that incandescent lamps are the least efficient of all electric lamp sources, they continue to be used extensively, particularly in the residential sector (Dutt n.d.). Since its conception, significant progress has been made in the efficiency of the incandescent bulb, taking its luminous efficiency from 3 lumens/Watt to 10-15 lumens/Watt. The prospects for future gains in the efficiency of incandescents does, however, appear limited. Electricity use in lighting is best reduced by replacing high-usage incandescent lamps with compact fluorescents and low-usage incandescent lamps with more efficient incandescent bulbs (Menanteau 1994).

3.2.2 *Fluorescent lighting*

The lighting efficiency of fluorescent tubes has grown steadily from about 32 lumens/Watt in 1936 to 100 lumens/Watt today. Their development has, nevertheless, remained limited, particularly in the residential market, owing to a number of reasons linked to their size, aesthetic problems and the quality of light (colour reproduction) which is less pleasing than those of incandescents (Menanteau 1994).

3.2.3 *Compact fluorescent lamps (CFLs)*

The advantages of using CFLs are as follows:

- they have a long life (can last up to ten times longer than standard incandescent lightbulbs) and do not have to be replaced frequently (Nadel 1991);
- they can achieve savings of up to 75% without decreasing light output;[7] and
- they give off light quality which can be compared with incandescents and thus present an improvement on the colour reproduction of standard fluorescent lighting.

They can penetrate the market easily, because:

- they are produced and offered by several major manufacturers;
- they produce a 'warm white light that is indistinguishable from incandescent bulbs' (Dutt n.d.: 9);
- they have light equivalents to all the standard incandescents (40, 60, 75 and 100 watts); and
- some can be screwed into incandescent sockets and, therefore, a change in fixture is not required.

Barriers to their implementation are:

- CFLs are considerably more expensive to purchase than incandescent bulbs. As a comparison, in the United States, an incandescent bulb retails at between $0.40 and $0.75, while a CFL retails at between $8 and $20, approximately 20 times the cost of the standard incandescent bulb (Dutt n.d.; Nadel 1991);
- the cost-effectiveness of CFLs is considerably reduced or eliminated where the price of electricity is subsidised, falling below the average and long-run marginal cost of supplying electricity;
- CFLs are generally not available in supermarkets and other retail outlets (Nadel 1991);
- the availability of CFLs is limited in many developing countries, where they are not manufactured domestically;
- import tariffs reduce the cost-effectiveness of imported CFLs;
- capital scarcity among potential users leads to high implicit discount rates for investment in energy efficiency;

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[7] That is, CFLs consume a quarter or less electricity to produce the same amount of light as incandescents (for example, a CFL that demands only 16 watts has the same rated light output as a 75-watt incandescent bulb) (Dutt n.d.).

- information about the technical and economic characteristics of CFLs is still limited and often comes from the manufacturers, who are not generally considered as reliable sources of information;
- CFL bulbs do not compare exactly with incandescents in terms of size, weight or external appearance. The CFLs may fit into the socket of an incandescent lightbulb, but their bulkiness may make it difficult to blend in with light fittings designed for use with incandescent bulbs;
- the cost-effectiveness of CFLs assumes an annual length of use in excess of 1 000 hours (that is, a 3-hour/day average), which limits the field of possible replacements in the residential sector;
- low motivation to achieve energy savings; and
- aversion to risk, especially among low-income households who are particularly sensitive to first costs (Menanteau 1994).

In spite of a purchase price some 15-20 times higher than that of incandescents, when its lighting efficiency and length of use are taken into account, CFLs constitute a cost-effective investment for the purchaser (Menanteau 1994). For lamps that are used only one or two hours a day, the investment in CFLs is not cost-effective and, therefore, it is suggested that CFLs are used for high-use lighting, while efficient incandescent bulbs are used for low-use lighting. More efficient incandescent bulbs are a recent development. They use approximately 10% less energy while providing the same level of illumination. They cost slightly more ($0.54 versus $0.39 for standard incandescent lamps in Brazil), but prove to be cost-effective, even in low-usage lighting (Dutt n.d.).

A number of programmes have achieved considerable success in promoting CFLs. These programmes differ in terms of the strategies employed, the incentives used, the certainty of savings and the administrative burden.

In industrialised countries, these measures have included:

- *Information programmes* - relatively little success on their own, but very important when combined with other measures.
- *Direct installation and free distribution* - electric utilities offer CFLs, free of charge, to their customers and offer installation assistance. These *give away* programmes traditionally target low-income groups. Information on the results of such programmes is limited, but it has been concluded that their success has been greater when community-based organisations have been involved in the marketing of the CFLs (Nadel 1991). In the USA, the utility Southern California Edison has initiated a lighting programme which offers free installation to low-income subscribers. This programme is conducted in collaboration with neighbourhood associations which approach these households and arrange the free distribution of the bulbs (Menanteau 1994).
- *Rebate coupons* - these coupons enable end-users to obtain reductions in the purchase of one or more CFLs. As a general rule, the reductions are between 20% and 50% of the public selling prices and apply to a limited number of bulbs. This is probably the most widely used method, although it does not always lead to very high participation rates. These programmes, usually initiated by electric utilities, may be carried out in collaboration with manufacturers and the distribution sector. In Amsterdam, for example, the programme initiated by the EBA electricity company has involved both manufacturers and the distribution sector, who have taken part in the information campaign and agreed to reduce their margins for the duration of the operation (Menanteau 1994). A further example is the rebate programme carried out by Ontario Hydro, a Canadian electric utility, which launched its residential efficient lighting programme in 1990. It offers rebates of $5 on the purchase of

energy-efficient CFLs from particular retail stores. In a period of just over three months, 120 000 of the bulbs were purchased, 20 times the amount sold the year before (Nadel 1991).

- *Leasing* - This type of programme allows the end-user to spread the payment for their purchase of CFLs over their electric bills. This procedure can achieve high participation rates. The EDFs (Electricite de France) Guadeloupe Programme is an example of a successful leasing programme. Its success is attributed to its individual approach of combining information, rebate coupons and in particular leasing. This programme resulted in the sale of a total number of 358 000 bulbs, a participation rate of 37% of the eligible households and an average number of 8 bulbs per household (Menanteau 1994). Leasing programmes are also low-cost measures. This is demonstrated by the example of the Taunton Municipal Lighting Plant in Massachusetts. It leases CFLs to customers at a cost of $0.20 per month included on the electric bill and guarantees that customers will save more than $50 in energy costs over the life of the bulb. The Taunton programme has reportedly cost the utility only $0.025 per kilowatt hour (Nadel 1991).
- *Mail-orders* - WEPCo (Wisconsin Electric Power Company) achieved a 7% participation rate in one year with a mail-order programme. Bulbs were purchased in bulk by the utility and sold to customers for an average of $2.50 a piece.
- *Charity sales* - CMP (Central Maine Power) achieved a participation rate in excess of 20% by promoting efficient lamps through the Lions Club annual lightbulb sale. Bulbs were purchased in bulk by the utility and sold at a discount of 72-84% off the normal retail cost. Available supplies were sold out within two weeks (Nadel 1991).

Conclusions drawn from these programmes are:

- The free distribution of bulbs produces the best results as far as participation rates are concerned (Menanteau 1994). An experimental programme, conducted by the utility Niagra Mohawk, in the United States, which offered end-users CFLs in combination with other energy saving measures (water-heater blankets, pipe wrap and low-flow showerheads) under three different financing arrangements - free, half-cost and at full cost, but financed through deferred payment of loan - demonstrates the effectiveness of different incentive methods. The result was that participation rates varied from 44% for the free offer to 6% for the half cost offer to 3% for the loan (Nadel 1991). Information on programme savings and cost-effectiveness are not available.
- When a financial involvement is required of the consumer, it seems that the incentive method chosen is more important than the value of the incentive itself (Menanteau 1994). For example, the possibility of spreading the initial investment over future electricity bills has a far more important influence on consumer decision-making than the mere selling price of the bulbs.
- The study by Atkinson et al (1992) shows that greater savings were achieved through mandatory rather than voluntary equipment standards.
- The mean cost of energy saved for the community is appreciably lower than the cost of electricity produced by a new conventional type power station and lower still than the cost of electricity produced at peak periods (Menanteau 1994).

Residential lighting programmes have also been adopted in developing countries. In Thailand, a residential lighting programme was initiated in order to reduce the future electricity demand expected from new electrical connections to low-income houses (Parker 1991). Lighting is often the first use of electrical energy in low-income households when they receive an electrical service. This, together with the fact that the load factor of lighting is poor, with the most consistent utilisation occurring during the peak load hours, makes lighting a significant contributor to household energy consumption. Most of the residential lighting in Thailand was, in the past, of the more efficient fluorescent type, but there was a move toward increased installation of incandescent lighting in new houses in more recent years. This led to a programme to promote CFLs in the residential sector.

Two types of CFLs were considered for the Thailand lighting programme:

- CFLs which screw directly into conventional lamp sockets; and
- CFLs which are directly hard-wired into the lighting fixtures and have substantially lower costs than the screw-in variety.

The screw-in variety is considered for the retrofitting of existing buildings, while the hard wired CFL is considered for new residential buildings because of its lower cost.

In Mexico, the *Ilumex* project is designed to replace 1.5-2 million incandescent bulbs with compact fluorescent lamps over a two-year period in residential households in two of Mexico's largest cities, Monterrey and Guadalajara. The project is being carried out by the Mexican electricity utility, Comisión Federal de Electricidad (CFE). The project was funded by internal CFE funds, a loan to CFE by the World Bank, grants from the Global Environmental Facility and the Norwegian Government, with funds from US Aid to perform the pre-feasibility study. Approximately half these funds are dedicated to a revolving fund to expand the Ilumex programme to the rest of Mexico's 15 million electrified households (De Buen 1995; Sathaye et al 1993).

The pre-feasibility study was conducted to determine the conservation potential of the project (De Buen 1995). The results showed a large evening (6 pm to 11 pm) peak demand which is roughly six times larger than the residential lighting demand during the rest of the day, and a smaller peak between 5 am and 7 am. Most lights in the two cities were incandescent bulbs (87% in Monterrey and 97% in Guadalajara). About 85% of fixtures were found to accept CFLs. Furthermore, about 93% of the households surveyed expressed an interest in using CFLs. The strategy to be employed by the utility is to share half the cost of the CFLs, as well as the cost of implementation. Utilities aim to target smaller consumers and lamps used at least four hours per day, thus ensuring that all end-users using more than 50 kWh per month have at most a two-year payback.

To date, Ilumex has gone through several stages and was ready to start operations in May of 1995. The implementation process of Ilumex has included the following steps:

1. feasibility study;
2. development of technical/economical specifications of the lamps;
3. international solicitation for CFLs;
4. creation of two private funds to operate the project in each city;
5. technical/economical evaluation to select the CFL models which are to be used in Ilumex;
6. design of operating procedures and manuals for private funds;
7. upgrade of CFEs billing system to provide the reports required by the World Bank; and
8. design of project evaluation procedures to comply with the World Bank requirements.

One of the most important technical characteristics of the Ilumex project is its tough specifications. Lamps which are able to withstand large variations in voltage are required and thus a technology procurement process was initiated. The offer of using the best-performing CFLs in Ilumex's demonstration programme and in future CFL programmes both in Mexico and in other parts of the developing world encouraged manufacturers to develop new CFL models able to withstand the 'rougher' grids of the developing world (De Buen 1995; IIEC 1993). Ilumex will begin with one delivery option and two purchasing options. The CFLs will be sold at CFE's agencies. The CFLs will be able to be purchased through cash or credit. The credit period will be two years, with credit payments being made bi-monthly. Customer outreach, through mobile trailers and door-to-door sales, is being considered, but it is thought that these methods will not be necessary (De Buen 1995).

3.3 Street lighting

A number of different systems of street lighting are used worldwide. These range in levels of energy efficiency from the least efficient incandescent lamps to slightly more efficient mercury vapour lamps and the most efficient high-pressure sodium lamps. The savings accrued as a result of switching from incandescent to more efficient street lighting is shown in the examples of Brazil and India.

A national electricity conservation program (PROCEL) began in Brazil at the end of 1985. As of early 1990, PROCEL had undertaken over 150 projects with a total budget of around $20 million. One of PROCEL's larger projects has been the replacement of incandescent street lighting with mercury vapour and high-pressure sodium lamps. Over 280 000 lamps were replaced between 1986 and 1989, with most of the cost being paid by PROCEL (Levine et al 1991).

Sale of electricity for public lighting was between 1.5 and 2 TWh in 1989/90. A wide range of technologies are used for street lighting in India, ranging in efficiency from incandescent (the least efficient) to high-pressure sodium (one of the most efficient) bulbs. The latter produces seven times as much light per unit of electrical output as an incandescent lamp (Dutt n.d.). Since public lighting is needed for about ten hours per night, these high-efficiency lamps are generally highly cost-effective. Dutt (n.d.) argues that it is better to use more efficient, more expensive high pressure sodium lamps than mercury vapour lamps which are less efficient and have a lower first cost (as have been used in Brazil). The reason for this is that the high pressure sodium lamps reduce electricity use immediately owing to their high end-use efficiency. Photocell sensors can also be used to control groups of lamps, turning them on and off according to daylight levels. Dutt (n.d.) estimates that a savings potential of at least 50% can be realised by replacing incandescent street lamps with high-pressure sodium lamps.

High-pressure sodium lamps give off white light at very high levels of efficacy. Although these lamps are more expensive than incandescent and mercury vapour lighting, they are cost-effective due to their high levels of usage. Switching from incandescent and mercury vapour to high-pressure sodium street lighting thus presents an effective energy efficiency strategy.

3.4 Refrigeration

In industrialised countries, excluding heaters and cookers, refrigerators are the dominant domestic appliance in terms of energy use. They also offer the greatest scope for energy reduction through the imposition of standards, because there are already models on the market which are substantially more energy-efficient than the average model in that category and thus efficiency improvements can be made at little or no cost (Waide 1993). A variety of programmes aimed at increasing the energy efficiency of refrigerators have been implemented internationally.

In 1980, German manufacturers entered into a *voluntary agreement* with their government to improve the energy efficiency of refrigerators and freezers by 15-20% from 1978 levels by 1985. These targets were exceeded by a substantial margin.

In the United States, the National Appliance Energy Conservation Act (NAECA) of 1990 imposed standards, to be implemented by 1993, which would reduce the average refrigeration units consumption of electricity by between 25% and 30%. For all classes of refrigerators, fridge-freezers and freezers, only seven out of the 2 114 models on the market in 1990 met the 1993 standards. The standards have been met, and exceeded, with only a 1% increase in cost of appliances to the consumer. The number of models available has not decreased, total sales have increased and the manufacturers are performing financially at least as well as they were prior to the standard being introduced. New standards for 1998 were due to be announced in 1995 and were expected to increase energy efficiency by a further 25 to 50% (Waide 1993). In July 1995, the US House of Representatives voted to cut funding for the DoE's building codes and energy efficiency standards programmes (Freedman 1995). This has brought the future energy savings from the US standards programme under serious question.

The Super Efficient Refrigerator Program (SERP) or 'Golden Carrot' has demonstrated the potential for yet further energy savings in US domestic refrigerators. SERP's challenge to manufacturers was to bring into commercial production, new models requiring 25% to 50% less power than current machines, and using non-ozone-depleting gases. The reward was a prize of $30 million in orders from electric utilities, who were willing to sponsor the reward in order to avoid the huge capital investments which would otherwise be required in building new power plants (Waide 1993).

The introduction of standards in the US has acted as a stimulus for *accelerated design strategies* which have boosted the manufacturers' technical position in relation to foreign producers. There is growing evidence that US manufacturers are now looking to penetrate lucrative overseas markets (especially Eastern Europe) as they perceive that they have attained a new competitive advantage over west European manufacturers (Waide 1993).

In developing countries, refrigerators are one of the first *major* electrical appliances acquired by low-income households. Increasing refrigerator consumption places an enormous strain on the electricity supply in these developing countries and, therefore, it is essential that energy-efficient refrigerators are promoted and fostered. For example, in China, there were no refrigerators manufactured locally in 1980, but more than eight million manufactured in 1990, and in India the projected growth in refrigerator ownership is from 4% of households in 1992 to 60% by 2015. This rapid growth in refrigeration use requires enormous growth in electricity supply just to meet the growing domestic refrigeration demand. If the refrigeration models adopted are inefficient, scarce capital will be drained and local air pollution and global warming problems will be exacerbated (Waide 1993).

In 1984, Brazil initiated a refrigerator efficiency programme consisting of efficiency testing and labelling. The result has been a reduction in the electricity consumption of residential refrigerators. This was achieved through improved insulation, more efficient motor-compressors and modified design of the refrigeration cycle. Encouraged by the progress achieved, and following the additional savings potential realised in some industrialised countries, in 1990 Brazil proposed minimum efficiency levels for refrigerators through agreements made between the government and manufacturers. These agreements require that by 1993, refrigerators in each category consume no more than the most efficient model available in 1989. The proposed agreement calls for efficiency improvements of 5% per annum from 1994 to 1998 and will lead to the 1998 models using only half as much electricity as those sold in 1990 (Dutt n.d.).

A number of lessons can be drawn out of the energy-efficient refrigerator programmes that have been implemented internationally. These are:

- the mere existence of energy-efficient models that are cost-effective to own and operate does not mean that consumers will make economically rational decisions. For energy-efficient refrigerators to penetrate the market, the efficiency of new refrigerator models must thus be tested and either minimum efficiency standards must be set (as in the United States) or manufacturers must agree on efficiency protocols (as in Brazil) (Dutt n.d.);

- in order to be effective, efficiency standards must exceed the natural technical development in refrigerator energy efficiency, resulting from manufacturers seeking to attain a competitive edge;[8] and
- proper enforcement of energy efficiency standards is crucial if real energy savings are to be realised. This enforcement should include independent testing of refrigerator performance for initial certification and inspection at the point of retail (Waide 1993).

3.5 Other

Other appliances vary substantially in their contribution to household energy consumption. In industrialised countries, appliances such as televisions, fans, dishwashers and washing machines may contribute a substantial amount to the energy consumption of the household. In low-income houses in developing countries, however, they contribute very little. The energy efficiency of these products should still be promoted, but it is essential to target those appliances which will have the greatest impact on household energy savings. With the exception of lighting, it is those appliances that consume the most energy that will be the easiest and most cost-effective to target in terms of energy efficiency policies and programmes.

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[8] For example, the improvement in energy efficiency of refrigeration units has been approximately 2.5% per annum in European countries and, therefore, if the European Commission's proposed -10% efficiency standard is delayed until 1997 as suggested, natural improvement in energy efficiency will already have exceeded that standard by 2% and thus the standard will be an ineffective instrument (Waide 1993).

CHAPTER FOUR

Implementation strategies for energy efficiency programmes

1. Introduction

To capture the potential for efficiency, policies are necessary to hasten the improvements in product efficiency, and to stimulate end-users to use more efficient appliances and strategies (Schipper & Hawk 1989). There are a number of reasons why intervention in the market is justified. These include:

- As a result of the increasing costs associated with meeting growing demands for energy, it is necessary to look to all methods of meeting those demands. Energy efficiency is a means of doing so, while improving access to energy services and reducing the environmental impacts of energy generation and consumption.
- Market failures, resulting from poor information and split incentives, inhibit the adoption of energy efficient measures and high end-user discount rates short-circuit the results of whatever marketplace process remains.

This chapter looks at policies and strategies which have been used internationally to effect the implementation of energy efficiency programmes. These strategies are diverse, both in their content focus and in the institution or set of institutions which implement them. The implementation strategies detailed in this chapter include fuel switching and optimal fuel mixes, information programmes, incentive schemes, regulatory codes and standards and price restructuring. The mechanisms for financing and the institutions required to implement these strategies are also discussed.

2. Optimal fuel mix

Past studies of energy use have been based on the notion that with economic growth and its associated urbanisation and industrialisation, developing nations will move up a fuel preference ladder,[1] switching from the use of traditional biomass fuels to 'modern' fossil fuels and electricity (Leach 1992). Barriers exist to this fuel transition and intervention is required to remove the stumbling blocks and allow for progression up the fuel ladder. Traditionally, relative fuel prices have been considered as a major factor in household fuel choices, but this does not generally appear to be the case. Various studies show that many poor households actually pay more for their fuels, on an energy-content basis, than do higher-income households (Sathaye & Tyler 1991). The main barriers to fuel switching are, therefore, identified as the first costs of modern fuel devices (such as appliances, liquefied petroleum gas bottles and/or electrical meter connection fees), the unreliability and/or inaccessibility of modern fuels, and the structure of payments for modern fuels[2] (Leach 1992; Sathaye & Tyler 1991). The major changes

[1] It is argued that the ideal fuel preference ladder would run from traditional biomass fuels up through kerosene to bottled gas (LPG), natural gas, electricity, and solar (Leach 1992). The preference for 'modern' fuels is cited as being a result of the convenience and cleanliness of use in comparison with traditional biomass fuels.

required for energy transition are, therefore, the improved distribution of modern fuels and sufficient income[3] to buy the modern fuel appliances, or conditions that lower appliance costs, making them accessible.

The process of energy transition is widespread in many households in developing countries and the shift from one fuel to another must be clearly understood. The notion of the fuel preference ladder is, however, found to be lacking as a means of understanding the reality of fuel-use within households, in terms of both the shifts between fuels and the multiple use of fuels within households. It is over-simplistic, suggesting a 'linear and deterministic process of movement, involving successive steps in either a backward or forward direction' (Eberhard & Van Horen 1995: 67). Energy transition theory and the concept of the fuel preference ladder have been criticised at a number of levels. Firstly, it has been criticised in terms of the *modernisation* paradigm which underlies transition theory. This assumes that individuals move from the 'traditional' to the 'modern' and from a state of 'natural' underdevelopment to a state of development. This process of modernisation ignores the 'impact of colonialism and the set of economic relations between countries in the North and South, and also between wealthier and more impoverished social formations within countries' (Eberhard & Van Horen 1995: 68). It neglects the fact that use of 'traditional' fuels does not 'reflect peoples free choices', but rather the political, economic and social forces which shape societal relationships. Secondly, it has been argued that the linkage between increasing income and progress up the ladder is misleading. Energy is an income-inelastic service and therefore the correlation between income and fuel use is weak. Other factors, such as access to alternative energy sources, reliability of income flows and service levels are more important determinants of fuel 'preference'. Thirdly, the fuel preference ladder lends itself to viewing electricity as the best way of meeting energy needs. Electricity is, however, not the most efficient source for providing *all* energy services. It has uni-functional end-uses and requires the purchase of separate appliances to meet each of the varied end-uses. An understanding of *multiple fuel use* is essential to developing an integrated energy plan which will employ an optimal mix of fuels to achieve the delivery of energy services in the most efficient manner. The energy transition model is not useful in explaining multiple fuel use. Multiple fuel use can only fit into the model as a state of transition - which is not the reason why such a phenomenon exists. An end-use perspective on energy delivery helps to identify the individual end-uses and the fuels which are best suited to meeting household energy needs. By identifying which fuels are most commonly used to satisfy the different end-uses in low-income households, one can determine which programmes will have the greatest impact and which technologies should be targeted by energy efficiency policies. Finally, the energy transition model ignores the issue of *energy security* within the household. The unreliability of the electricity system results in households maintaining back up fuel-appliance combinations over and above purchasing new electric appliances (Eberhard & Van Horen 1995).

The importance of integrated energy planning to facilitate an optimal mix of fuels is illustrated by the following example. In low-income households, the most common end-use for electricity is lighting. After lighting, irons and television sets seem to be the first appliances purchased by

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[2] Modern fuels must be paid for in lump sums, while traditional biomass fuels, where purchased, are bought in small amounts, at small cost, on a daily basis. Because their incomes are often periodic, avoiding lumpy payments is a major household strategy for the poor, even if it requires paying more for the fuel in the end (Leach 1992).

[3] Rising incomes are often considered to be the main reason for the occurrence of the energy transition. The notion of the *fuel/income ladder* has thus been developed to explain the shift to more convenient and higher-quality fuels as household incomes pass certain thresholds (Sathaye & Tyler 1991).

households. Refrigerators are usually next in line,[4] followed by washing machines, electric water-heaters and air-conditioners, depending on climatic conditions, income levels and cultural traditions (Sathaye & Tyler 1991). Cooking and space-heating often continue to be met simultaneously through alternative energy sources. Integrated energy planning and the end-use oriented approach facilitates a more accurate understanding of household energy needs, thus ensuring a more appropriate response to meeting energy needs.

3. Information programmes

This section covers five types of programmes - appliance labelling, energy audits, training, general information and research and development. There is variation in terms of complexity, resource-intensity and the cost of implementation both within and between these different programme-types.

3.1 Appliance labelling

The primary goals of appliance labelling initiatives are to increase awareness of energy consumption and the potential for end-use efficiency, and to provide unbiased information to aid the purchasing decision (IEA 1989). It is expected that through raising the awareness among end-users, their purchasing practices will shift toward the more energy efficient products, thereby expanding the market place for these types of products and speeding up the commercialisation of new technologies. The objective of *product-rating, certification* and *labelling* programmes is, therefore, to try to improve the information available about the energy use of different products. It is believed that such programmes will help to overcome the barrier of misleading, absent or confusing information surrounding energy efficient technologies. Consumers will thus be made aware of the long-term savings and environmental benefits of buying energy efficient products. Manufacturers will also be encouraged to develop new energy-saving technology (Casey-McCabe & Harris 1995).

There are two main types of appliance labelling programmes which have been implemented. These are:

- *endorsement labelling* programmes which identify and endorse a limited number of products which meet a specified performance level; and
- *comparison labelling* programmes which offer a means for buyers to compare similar products and make more informed choices on the basis of energy efficiency and other criteria.

The labelling programmes instituted vary on other counts. These include:

- The group responsible for the introduction of the programmes differs - programmes have been instituted by government agencies, manufacturers, industry associations, 'third-party' environmental groups, consumer advocates and utilities.
- The group incurring the cost of the programme differs - some programmes are fee-based and require that manufacturers pay to have their product certified, while others are programme-funded and conduct performance rating and labelling of all products of a particular type on the market.

3.1.1 Endorsement labelling programmes

Endorsement labelling programmes help consumers to distinguish between similar products by performing investigations and comparisons, and providing the potential buyer with a single 'seal of approval' for those products which meet or exceed established criteria. Some

[4] For example, in newly-electrified South African townships, some residents have purchased refrigerators as a business venture, using them to store food and/or ice for sale.

programmes attempt to target the upper percentage of products on the market in terms of energy efficiency, while others try to encourage the purchase of a particular class of products (for example, thermal insulation), rather than distinguishing between more and less efficient products in a given category (Casey-McCabe & Harris 1995).

Table 4.1 summarises selected endorsement labelling programmes in the United States, Canada and Europe. While all the programmes evaluated are voluntary, they vary in terms of implementing agencies, requirements, range of products and who bears the burden of costs of product testing and implementation. The differences in these programmes have implications for their success. The key issues emerging from this comparative analysis are:

- Those programmes which are implemented by third parties, such as utility consortiums (Power Smart) and non-government organisations (Green Seal) are *fee-based*, requiring that manufacturers pay to have their products certified. Government-implemented programmes are, on the other hand, more often *programme-funded*. Where fee-based funding occurs, manufacturer participation rates may be low. This has implications for the legitimacy of the label because the products which are considered for, and receive, endorsement may not be representative of the range of products on the market. This demonstrates the significance of government involvement in labelling programmes.
- While some requirements for endorsement are based on specified efficiency guidelines (for example, Energy Star is based on EPA guidelines and Environmental Choice is based on programme guidelines), endorsement labelling programmes predominantly target those products which fall within the specified top percentile range for energy efficiency of existing models on the market. The latter method of selecting products for endorsement does not set efficiency targets for manufacturers and, therefore, it is questionable as to whether this results in technological advancement.
- A significant factor contributing to the success of endorsement labelling programmes is the simultaneous implementation of information programmes which create public awareness of the labels and the importance of energy efficiency.

	Energy Star (United States)	E-2000 (Swiss)	Power Smart (Canada)	BPA's Blue Ribbon Award Campaign (US)	Green Seal (US)	Environmental Choice (Canada)	European Community Ecolabeling
Implemented by	Government	Government	Power Smart Incorporated - a third party concern owned by seven Canadian utilities	Bonneville Power Administration - a US federal power marketing agency	Green Seal, a non-profit NGO in the US	Government	Member States of the European Community
Focus	Energy efficiency	Energy efficiency	Energy efficiency	Energy efficiency	General Environmental	General Environmental	General Environmental
Commitment	Voluntary	Voluntary	Voluntary	*	Voluntary	Voluntary	Voluntary
Target sector	Office equipment, but plan to expand to home appliances	Office equipment	All	Refrigerators and freezers	All energy-saving and environ-mentally preferable products	All energy-saving and environ-mentally preferable products	All energy-saving and environ-mentally preferable products
Who conducts product testing and certification	Manufacturer	Swiss government	Power Smart Incorporated	*	Green Seal accredited laboratories	Independent verification and testing	Manufacturer
'Fee-based' or 'Programme-funded'	Programme-funded	Programme-funded	Fee-based	Programme-funded	Fee-based	Fee-based	Fee-based
Requirements	EPA requirements	Products which are in the top 30% for energy-efficiency	Products ranging between the top 3 and 40% (depending on the appliance) for energy efficiency	Products which are in the top 15% for energy efficiency	Models which are in the top 15-20% of models on the market	Models which meet the Environmental Choice Programme guidelines for products and services	Models which meet guidelines based on 'cradle-to-grave' assessments and adopted by the EC Commission
Results	Some technological improvements	*	Reported high level of awareness of their label and increased sales in energy efficient products	Reported that about 22% of end-users influenced by campaign and retailers used labels as a selling point	*	Relatively low consumer recognition of the label and low public demand for labelled products	*
Simultaneous Programmes	Recently launched ad campaign to increase program awareness	*	A range of marketing tools and DSM programmes	Advertisement and other promotional campaigns	Public awareness campaigns to promote label recognition	Recently began marketing campaign of label and environmental awareness	*

* Information is not available.

TABLE 4.1: Summary of selected endorsement labelling programmes (Casey-McCabe & Harris 1995)

3.1.2 Comparison labelling programmes

Comparison labelling programmes attempt to provide the end-users with information on all or most of the models within a given product category, leaving it to each buyer to evaluate energy efficiency along with price, convenience and reliability. 'Comparison' labels typically use a set of standardised information to report on the labelled model's energy performance characteristics (for example, annual energy use, energy operating cost, or an efficiency index) and often includes the model's performance as compared to similar models. The assumption is that if consumers have easy access to comparable energy performance information they will make better informed decisions and select products that are more energy efficient (Casey-McCabe & Harris 1995).

Table 4.2 provides a summary of selected comparison labelling programmes in the United States, Canada, Europe, Australia and Brazil. Many of these programmes have been recently established and, therefore, there has been little evaluation of their success. There are four key issues emerging out of this comparative analysis. These are:

- The content of the energy labels is vitally important - they must be visible, clear and easy to understand, comparisons between products thereby made easy. Research needs to be conducted into what information end-users best respond to (for example, energy cost versus energy use) and how to best represent the graphical information. Internationally, there has been a trend toward information on energy *use* and away from energy *cost*.
- Provision of sales aids and promotional literature to train sales people on how to sell energy efficient equipment, and creating awareness of the labels through public information programmes, are essential components of a successful labelling programme.
- It is not always the end-user who is most influenced by the labelling programme. The success of the programme is often attributed to efforts of manufacturers, who respond to the programme as a challenge, creating more efficient products. Furthermore, landlords, building contractors and developers are often more influential in the purchasing process than the end-users. The labelling programme must thus be designed with these influential players in mind.
- Where compliance is voluntary, as in Brazil, close collaboration between the implementing agency and manufacturers (on setting priorities for the programme and negotiating standards) is essential to the programme success (see Box 4.1 for more details on this process).

	Energy Guide (United States)	*EnerGuide (Canada)*	*Brazilian Labelling Programme*	*Energy star rating (Australia)*	*European Community Energy Labelling*
Implemented by	Government	Government	Government	State government	EC Council Directive
Compliance	Mandatory	Mandatory	Voluntary cooperation between government and manufacturers	Mandatory, through legislation and regulation	*
Target products	Household appliances (refrigerators, air conditioners, heat pumps, freezers, water-heaters, dishwashers, clothes-washers, furnaces, certain lamps)	Refrigerators, freezers, dishwashers, clothes-washers and clothes-dryers	Initially refrigerators only, extended to electric showers and air conditioners and reactors for fluorescent lamps	Initially refrigerators, but extended to freezers, air conditioners, water heaters and dishwashers	Danish pilot study for the EC labelling programme focused on household appliances - refrigerators and freezers
Accompanying programmes	Education campaign to encourage awareness of labels; appliance labelling rule sets out specifications for appliances sold in the United States; National Appliance Conservation Act (1978) and Energy Policy Act (1992) provide for the DoE to set minimum efficiency levels for a wide range of products.	EnerGuide directory published annually and listing by product category and class, all the new models for sale in Canada, from most efficient to least efficient	General information programmes about energy efficiency. Independent performance testing and establishment of negotiated standards.	Legislation sets out offences and penalties if party does not comply	Promotional literature and sales aids given to store's salespeople; advertising and marketing in retail stores.
Label information	Energy Guide labels show the estimated yearly energy cost to operate household appliances, along with a scale of comparison for similar appliances. Recent shift in focus from cost to energy use. For climate control equipment (air conditioners and heat pumps),, Energy Guide labels have a numerical rating of energy use, with a scale for product comparison.	Labels include a scale of energy performance which enables consumers to compare the model with others within the same class for type and capacity; yearly energy consumption and emphasis on actual energy usage rather than annual energy cost.	*	Labels include estimated amount of appliance's annual electricity use in kWh; graphical representation using a star rating system of one to six stars, indicating the efficiency of the appliance in comparison to other models of similar size and features. Also have detailed energy listings of appliances with information on brand model, retail price and energy rating.	Labels contain the manufacturer, make and model of the product; graphical representation of energy efficiency ranging from the letter A with a green arrow (more efficient) to G with a red arrow (less efficient) and an arrow representing the position of the particular model on the efficiency scale; the energy consumption in kWh per year.

Results	Labelling programme demonstrates that while information programmes do result in some improvements in energy efficiency, a large proportion of end-users will not be directly impacted by appliance labelling, because they are not responsible for the purchase of the appliances - owners of rented buildings, construction companies and others are the ones responsible and their primary concern is to reduce first costs.	The Energuide programme is thought to have been successful, not because of increased awareness among appliance purchasers, but because it introduced an element of competition between the manufacturers, thus encouraging the development of more efficient appliances.	*	In 1987, the New South Wales labelling programme claimed a 15% decrease in energy consumption of refrigerators in the most popular size range sold. This saves end-users A$12 per year or A$180 over the 15 year appliance life-span.	The Danish pilot programme for the EC energy labelling was successful in influencing the choice of refrigerator and freezer made by consumers. It also resulted in an increasing turnover in efficiency products. The success has been attributed the simplicity of the label and to the extensive marketing and training programme that was undertaken simultaneously.

* No information available.

TABLE 4.2: Summary of selected comparison labelling programmes (Sourced from Casey-McCabe & Harris 1995, Freedman 1995, Uken & Beute 1991 and Mabuse 1995)

The Brazilian Programme for Electricity Conservation (PROCEL) has implemented an appliance labelling programme which not only demonstrates the potential success of such programmes in developing countries, but shows the steps taken to design and implement such a programme. The primary goal of the labelling programme was to inform prospective appliance buyers of their energy consumption, thereby influencing their end-use energy efficiency. The first appliances to be labelled were refrigerators. These were selected on the criteria that they contribute more to peak demand.

The following steps were taken to initiate and implement the refrigeration labelling programme:

- a protocol was signed between the Brazilian government and refrigerator makers to assign priorities for the labelling programme;
- the information content of the labels was defined;
- testing procedures were designed under Brazilian technical norms; and
- a laboratory was set up with PROCEL funds to test the refrigeration equipment.

Other appliances which have since been included in the programme are electric showers and air conditioning systems. Plans have also been made to determine test procedures for reactors for fluorescent lamps (De Araújo et al n.d.). Additional laboratories have been set up with PROCEL funds to test these appliances.

The following procedures are followed in the labelling programme:

- technical information about the efficiency of the appliances is compiled by the manufacturers and submitted to authorised laboratories which check the information;
- the information is then verified by the National Institute of Etrology, Normalisation and Industrial Quality (INMETRO) through a series of tests, measurements and controls have been conducted; and
- clearly visible energy efficiency labels are attached to the appliances on sale (Levine et al 1992).

Labelling of refrigerators and freezers has proved to be one of the most successful programmes in the Brazilian energy conservation campaign. This was due less to consumer choice than to manufacturers, who responded by improving their products, on the one hand, and retiring less efficient models from the market, on the other (Levine et al 1992). This can be attributed to the fact that in developing countries manufacturers are keenly aware of a potential competitive advantage and, therefore, appliance labelling programmes can result in substantial energy efficiency improvements by the appliance manufacturers themselves (Parker 1991).

The programme has been followed up by agreements with producers to set goals for minimum standards over a period of five years. De Araújo et al (n.d.) attribute the effectiveness of this programme to the following:

- the definition of norms and standards;
- the setting up of certified laboratories for product testing and certification;
- technical empowerment; and
- collaboration with manufacturers and industry involved.

BOX 4.1: PROCEL's appliance labelling programme

3.1.3 Evaluation of labelling programmes

There are several important lessons which emerge from an evaluation of the successes and failures of and differences and similarities between international appliance labelling programmes. These are listed below.

- *Information* and *promotion* is vital to the success of the labelling programmes. Carefully planned, sustained programmes to inform both sales people and customers about the label are essential to a successful labelling programme. This is demonstrated in the Danish pilot programmes for the EC energy labels and in the BPA programme evaluation (Casey-McCabe & Harris 1995).
- There are advantages and disadvantages of both *fee-based* and *programme-funded* labelling programmes. With fee-based programmes, there will be a number of products on the market which will not be rated, certified or labelled, owing to the fact that the manufacturers may be unwilling, unaware or unable to participate in the programme. It is possible, therefore, that the most efficient items available on the market will not be labelled. On the positive side, fee-based programmes usually make use of an independent agency for certification, increasing the legitimacy of the label. On the other hand, while programme-funded programmes potentially experience higher participation rates, they have typically relied on energy efficiency data supplied by the manufacturers themselves, instead of an independent unbiased source and, therefore, this data could possibly be a misrepresentation of a product's attributes.
- While *voluntary* labelling programmes are often extolled for their fairness, *mandatory* programmes generally have much higher rates of participation. Manufacturer participation rates vary substantially in voluntary programmes. In some programmes, manufacturers responded positively, submitting their products for rating and introducing new and more efficient products. It has been noted that smaller manufacturers, especially those with small advertising budgets, were more eager to take part and get their products certified and labelled as they saw it as an opportunity to market their products. Some manufacturers saw the programmes as a market intrusion and, therefore, participation rates were low. Where manufacturer participation rates are low, information may be misleading, as the labelled products represent only a proportion of the potential energy efficient products available on the market. In some cases, for example, in France, labelling is mandatory only for products sold and not for products displayed (Mabuse 1995). This has a negative impact on the success of the appliance labelling programme.
- It is essential that the *accuracy* of the energy efficiency information is legitimate so that the end-users can do comparative shopping, utilities can decide which models to promote and public officials can track the progress that manufacturers are making in improving efficiency (Nadel et al n.d.). Appliance efficiency testing, therefore, needs to be standardised, either by agreement between the manufacturers or by establishing a national testing programme, which should include the testing of imported equipment.
- The *format* of and *information* on the label is essential to the success of the labelling programme. Research is required to determine what end-users best respond to - graphical representations such as endorsement logos or scales of comparison. With regards to the information on 'comparison labels', it is necessary to understand what measures of comparison end-users will best respond to - energy units, monetary units or efficiency indices. In the United States, there has recently been a shift from using comparative cost information to using comparative information on energy use, as it is believed that consumers respond more positively to consumption information.
- The Brazilian labelling programme demonstrates the importance of engaging manufacturers in the process. Close collaboration between the government and manufacturers resulted in

manufacturers perceiving a competitive advantage in energy efficient equipment and, therefore, altering their behaviour to transform the market supply.

3.2 Energy Audits

Energy audits provide information on the energy consumption characteristics of end-users, and indicate ways of reducing energy bills (for example, energy efficiency actions, shifting to another fuel or changing tariff structures). The primary goals of these audit programmes are to address market limitations (such as lack of information and invisibility) and to stimulate consumer action by promoting awareness of energy waste and energy efficiency improvements (IEA 1989). Energy audit programmes vary both in terms of the agents of implementation and in terms of the costs and effort for the implementing agencies. Energy audits can be undertaken by government energy efficiency agencies, private consultants (for example, energy service companies) and electric and gas utilities (Lapillonne 1993).

Financial support varies considerably between energy audit programmes. In Europe, different financing mechanisms have been tried at different periods. Energy audits have been subsidised and provided at no cost (100% subsidy) or low cost (partial subsidy). In some cases, the audits are reimbursed only if the investments recommended in the audit are made afterwards. In other cases, the audits are a condition to have access to loans (Lapillonne 1993). The Danish heating-audit scheme is a good example of the various financial support mechanisms which are available for such audits as it has employed and discarded a number of techniques over time (Box 4.2).

In the Danish heating-audit scheme, *investment grants* were initially given only after an audit had been conducted. The grant could be used to reimburse the audit cost. This was thought to be the best strategy because audits would be subsidised only if they resulted in an investment, and investment subsidies would be given only on the basis of an audit report. This programme was unpopular, however, as the end-users were reluctant to advance the cost of the audit.

The scheme was then adjusted to make it less constraining: audits were *fully subsidised* and investment grants were given without guarantee of investments being made. The programme became very popular.

The granting of free audits with no guarantee of investments being made was regarded as a waste of public funds and the programme was adapted again. Audits were only *partially subsidised* and investment subsidies were granted only if the heating-audit report recommended investments (Jordal-Jørgensen & Larsen 1995). A large number of audits were conducted under this scheme. The number of heating-audits reached its peak at about 140 000 in 1984. Between 1980 and 1985, subsidies in connection with the heating-audit scheme amounted to ECU 300 million.

In 1984, the subsidy scheme was stopped and the Heating-Audit Act was promulgated. This law requires that a heating audit report is available for the new owner whenever a house built before 1979 is sold. Old houses that meet the standard can be endorsed with a certificate, but the certificate is not required by law. There is no sanction within the law if a heating audit is not carried out when the house is sold. It is up to the new owner to demand a heating audit. The number of sales of homes with heating audits is falling.

BOX 4.2: Danish heat audit scheme (Lapillonne 1993)

Energy audits also vary in terms of their comprehensiveness. There are 'light audits' which can be carried out quickly with limited information and there are comprehensive audits which imply measurements and may include feasibility studies for energy efficiency investments (Lapillonne 1993).

Energy audits can be *identifier* programmes. For example, Ontario Hydro runs a residential audit programme which demonstrates to end-users where and how energy can be saved, detailing the appropriate energy saving measures, along with the existing Ontario Hydro incentive programmes, in an energy-use report to the customer following the audit. This audit consists of an information package with a questionnaire which is mailed to customers in single-family dwellings. The questionnaire asks for information detailing customer energy uses, lifestyle and home characteristics. When returned, the questionnaire is processed and a computerised report is prepared for each customer. The audit shows where household energy is used and makes recommendations to customers on how they can improve efficiency and comfort in their homes. Ontario Hydro (1991) reports that participation rates have averaged at about 45% and that customer response has been very favourable.

In Thailand, it has been proposed that cost-free energy audits be provided to households who want assistance to reduce their monthly bill or who have been identified from billing records as users of excessive amounts of electricity. These audits would examine the equipment and structure of the homes and provide recommendations to the occupants. Some simple maintenance tasks such as cleaning the refrigerator and air conditioner evaporator coils could be performed on the premises. Households will also be made aware of available rebates or direct installation programmes which may be applicable to their circumstances (Parker 1991).

The Danish heating-audit scheme represents a *comprehensive* auditing programme. Heating consultants carry out extensive heating audits and recommend measures based on a cost-effectiveness criterion of a payback period of approximately ten years (Jordal-Jørgensen & Larsen 1995). These audits are potentially carried out on all buildings. There are, however, problems with the cost-effectiveness of comprehensive audits. In Denmark, it has been observed that energy savings related to energy audits are too expensive and it has been suggested that the cost of heating audits be lowered by including only the most important energy efficient measures in the audit and by limiting the audits to buildings with large potentials for energy savings.

In the United States, there has been a move toward reducing audit complexity and costs, while increasing the implementation of audit recommendations (Nadel 1991). An example of this is the Boston Edison's EASY programme which uses a simplified auditing procedure and a small portable computer to generate an audit report while the auditor is still in the home. The auditor then explains the audit results to the home owner and highlights the most important recommendations. In addition, the auditor installs up to $25 worth of free conservation materials at the time of the audit. The trust of the home owner is gained by contracting local community organisations to perform the audits.

There are a number of key issues which emerge out of an evaluation of energy auditing. These are:

- energy auditing schemes are relatively labour intensive and can, therefore, generate employment (Jordal-Jørgensen & Larsen 1995);
- audits conducted by trusted agencies, such as community organisations, are likely to receive more positive responses from the participants (Nadel 1991);
- simplified auditing schemes are more cost-effective; and
- higher participation rates are experienced where financial assistance is provided and where arrangements are made to help end-users receive assistance in installing energy efficiency measures.

3.3 Training

Training of agencies and staff implementing energy efficiency is vitally important to the successful application of energy efficiency improvements. Training of energy auditors, energy managers, inspectors enforcing efficiency regulations, building designers and architects, utility and government staff who plan and operate efficiency programmes and those who provide technical assistance as part of energy conservation programmes is, therefore, required (Nadel et al n.d.). This training can occur in a number of forms, ranging from seminars and workshops to post-graduate degree programmes at technikons and universities.

Training programmes have been established in a number of different countries. They are usually linked to other programmes, providing training for staff around the necessary technical skills, implementation and operation of such programmes.

In India, the Energy Management Centre (EMC)[5] started an initiative to train energy managers and auditors to support the subsidised energy audit programme (Dutt n.d.). It was found that there were insufficient auditors to implement the programme successfully and, therefore, the training programme hoped to alleviate the shortage. Apart from the initial training, ongoing training updates and newsletters were established to apprise energy auditors of new technologies and conservation opportunities.

In Thailand, training sessions have been held for utility and government officials on the concept of least-cost utility planning. This involved a two-week seminar given by foreign trainers where the analysis of electricity end-use, and opportunities to reduce electricity use through efficiency measures, were discussed. The result of these efforts was the establishment of efficiency programmes by Thai utilities. Follow-up workshops have focused on the planning and design of utility-sponsored efficiency programmes (Nadel et al n.d.).

In the United States, utilities have instituted training as an extension of residential new construction programmes. This has involved both the training of builders on how to build and sell an energy efficient home and the training of architects and engineers on reducing energy use in new buildings through improved building design (Nadel 1991). Education, training and design assistance has been identified as one of the important components of successful new construction programmes. A similar programme has been proposed by Tenaga Nasional Berhad (TNB) in Malaysia. TNB, in cooperation with existing professional organisations, proposes to organise training courses for design, construction and maintenance professions on the topics of increasing the efficiency of structures, equipment and processes. These courses specifically target the issues of energy efficient architecture, building energy use simulation, energy efficient lighting design and efficient cooling system selection and design. The costs of this initiative will be kept low by encouraging suppliers of energy efficient equipment to sponsor seminars and by encouraging experts to offer courses free of charge (IIEC 1994a).

3.4 General information programmes

Studies in the United States have shown that the provision of general energy conservation information through brochures and advertisements can raise public awareness, but is unlikely to have an effect on actual end-user consumption behaviour unless it is part of a comprehensive effort including technical assistance, correct pricing signals, financing and efficiency regulations (Nadel et al n.d.)

Data on residential information programmes is limited, but research seems to indicate that such programmes are most effective when:

- programmes provide end-users with simple and specific steps to take along with estimates of how much energy and money can be saved; and

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[5] The Energy Management Centre (EMC) is a sector of the Department of Power, Ministry of Energy, Government of India, which was set up in 1989 with the assistance of the European Economic Community in order to coordinate the fragmented energy initiatives that were under way in India. It aims to provide an overall strategic vision, based on quantitative analysis, of what needs to be done to improve energy efficiency in the Indian economy.

- the information is provided by a trusted and respected organisation whose motives are clear and unambiguous.

In the United States, some of the larger utilities such as Pacific Gas & Electric Company, provide general information programmes for their customers in the form of brochures and telephonic assistance lines. The information brochures cover a wide range of energy-saving technologies and strategies, including weatherisation, appliance efficiency (such as energy efficient lighting and refrigerators), efficient water-heaters, conservation behaviour within the home and time-of-use rates (PG&E 1993a). Included in the brochures are facts about energy and monetary savings that can be made through the adoption of energy efficient improvements. Furthermore, these brochures specify technical and financial assistance programmes offered by the utility and are complemented by a comprehensive billing system, which enables end-users to compare their month's energy bill with the same month in the previous year, thus allowing consumers to identify their energy savings.

Thailand proposes to implement general information programmes which inform the consumer on how best to use electricity. These will include brochures made available on a variety of topics such as energy efficient lighting, how to purchase efficient appliances and methods to reduce air conditioning costs; public service advertising on radio and television and in newspapers describing available DSM utility programmes and how end-users can participate; and comparisons of this month's electrical consumption versus the same month in the previous year on the monthly electricity bill, thus providing feedback to end-users on how their electrical use may be changing (Parker 1991).

3.5 Research and development

Though many energy efficiency and renewable technologies are already technically viable and cost-effective, others require further development. Research and development (R&D) activities can be used to develop new energy-saving technologies or to adapt existing energy efficient technologies to local needs and production processes (Nadel et al n.d.). Therefore, if energy efficiency improvements are to continue into the future, it is essential that research and development activities are encouraged in this field.

There are other benefits to energy efficiency R&D:

- it serves to increase technical confidence in new technologies and methods, thereby overcoming institutional resistance to change;
- it acts to develop new skill and expertise within individual companies, if carried out in conjunction with industry; and
- it serves to increase awareness of the importance of energy efficiency and environmental improvement (Jackson 1992).

The amount of R&D carried out will be directly related to the funding available for the purpose. Although it is possible that some private sector concerns will be involved in energy efficiency R&D, it is unlikely that this will generally be the case. The reason for this is that there is a limit to the amount of time and effort they can devote to what is still an uncertain and infant market. It follows, therefore, that there is a significant role for government coordination and funding in the furthering and promoting of R&D (Jackson 1992).

Internationally, energy research and development has been grossly skewed in favour of fossil fuels and nuclear power. In the IEA countries, these energy sectors have received three-quarters of all energy R&D funding, while energy efficiency and renewables have received just 16%. The South African energy budget reflect these proportions, with 70% of the budget being dedicated to nuclear research and only a small percentage being dedicated to energy efficiency and energy conservation. A vital requirement of national and international energy R&D programmes should be to direct funds away from nuclear power and fossil fuels and toward energy efficiency and renewable energy technologies (Greenpeace 1992).

Government energy R&D expenditure is important for a number of reasons:

- it sends important signals to industry, manufacturers and the energy market about energy policy directions and objectives;
- it can accelerate the development of new technologies;
- coordinated international research enables benefits to accrue to groups of collaborating countries;
- market barriers, such as pricing coal- and nuclear-based electricity below their long-run marginal cost curves, and government subsidies of these energy sources, inhibit the entry of energy efficiency technologies into the energy market and thus it is necessary for government to correct these market failures;
- the private sector is unlikely to independently invest in energy R&D as they consider these to be long-term technologies; and
- the private sector is often unwilling to undertake the scale of investment necessary for a technology to become economically viable (Greenpeace 1992).

4. Financial incentives

This section is concerned with financial incentives which are offered to the different stakeholders - end-users, manufacturers and energy suppliers - to encourage energy efficiency investments. Each stakeholder group is addressed separately, identifying the types of incentives which have been offered internationally and the success or failure of such schemes.

4.1 End-user incentives

Essentially, the objective of end-user incentives is to provide funds to end-users to stimulate energy efficiency investments in existing buildings, equipment or choice of energy efficient techniques (Lapillonne 1993). In principle, these incentives should relate to actions that are cost-effective from the point of view of the societal good, but would not be undertaken by end-users for a variety of reasons, such as poor information, lack of capital to overcome first costs and split incentives.

4.1.1 Grants and subsidies

Grants and subsidies are direct or indirect payments to an individual or class of end-users, which give the recipients a financial incentive to purchase a particular good or service. Consumer subsidies are usually given to induce certain behaviour, such as the installation of more energy efficient equipment (IEA 1989). The primary goal of grants is to address market limitations of financial attractiveness and access, lack of information and confidence and separation of expenditure and benefit, by stimulating discrete investment in energy efficient technologies or services. Grants have elicited high participation rates and have been successful in creating awareness, providing information to end-users and improving financial attractiveness of energy efficient measures. However, they are administratively expensive and costly (IEA 1989).

Grants or direct subsidies for energy efficiency improvements were widespread in Europe in the 1970s and early 1980s (Lapillonne 1993). These grants were either defined as a fixed amount or as a percentage of the investments (with a ceiling), or as a sum proportional to the amount of energy saved. In most European countries these grants were reduced or stopped in the mid-1980s. The reasons for this are:

- *budgetary constraints* resulted in the cutting of grants which require large pools of funds;
- the procedures required to be eligible for the grants were too *bureaucratic* and, therefore, end-users were dissuaded from applying for them;
- the *operating costs* of these procedures were too high; and
- these schemes often attracted *free riders*, that is, those who used the grants were the higher income households who would have carried out the investments even without the incentive, while lower income households continued to be neglected by the scheme (this can be attributed to the fact that many of the low-income target group were unaware of the scheme, owing to poor information).

Grant schemes have since been altered to reach a specific target population only. These grants are offered only to specific target groups, such as tenants and low-income groups. In many cases, grants have been replaced by subsidies to help the investment decision, such as subsidies for energy audits.

Subsidies can be expensive and, once established, quite difficult to withdraw as the subsidised group becomes used to operating under the lower cost condition. Subsidies should, therefore, be used as temporary market assistance for new technologies, rather than as long-standing, broader subsidy schemes (IEA 1989).

4.1.2 Rebates

Many utilities offer cash rebate payments to buyers of energy efficient equipment, while some offer rebates to sellers of efficient equipment. These programmes have been fairly successful in inducing end-users to undertake energy conservation actions. The most successful programmes have been those that combine simple programme procedures that are easy to understand with extensive marketing and free technical assistance (Nadel et al n.d.).

In the United States, many utilities have offered rebates to end-users for the purchase of refrigerators, air-conditioners and water-heaters whose efficiency exceeds the threshold efficiency level set by the utility. Participation rates and energy savings vary from programme to programme, depending on how aggressively they are marketed and on how efficient the appliance must be to qualify for the rebate. In order to gain high participation rates and energy savings, while minimising free-riders, it is necessary to set relatively high efficiency levels for eligible appliances and pursue a strong marketing campaign. As minimum efficiency standards are raised and inefficient appliances are eliminated from the market, the continuance of these rebate programmes come into question. Some utilities in the United States, for example PG&E, have continued to use rebate programmes in an innovative way. They offer rebates of $50 for refrigerators that exceed the 1990 federal efficiency standards by 10% and $100 for refrigerators that exceed the standards by 15% (Nadel 1991). In this way, they create market demand for the most efficient products and stimulate manufacturers to react to this demand and create even more efficient products (Turiel et al 1991).

A number of conclusions can be drawn from international experience with residential rebate programmes. These include:

- rebate programmes are most successful when their design is kept simple (Geller & Nadel 1994);
- the efficiency threshold for appliance rebate eligibility should be relatively high;
- rebate programmes are most effective when accompanied by a personal one-on-one marketing strategy;

- the rebate amount for the equipment should not be greater than the incremental cost of more efficient models, other wise, the rebate could encourage higher equipment saturation levels, thereby defeating the purpose of the programme[6] (Nadel et al n.d.); and
- rebate programmes can be used as incentives to stimulate manufacturer production of more energy efficient goods.

4.1.3 Loans

Zero-interest or low-interest loan programmes can provide end-users with the capital necessary to make energy efficiency improvements. Such loan programmes have been implemented by utilities in the United States with varying rates of success.

The Tennessee Valley Authority (TVA) Home Weatherisation programme, which ran between 1977 and 1989, combined audits with contractor referrals and zero-interest loans.[7] Simple information programmes were run simultaneously, resulting in high participation rates and savings. During the run of the programme, 62% of all electrically heated houses were weatherised, with the average investment in the home being approximately $1 000. Energy efficiency measures installed included insulation, weather stripping, storm windows and caulking. Annual savings were estimated at 3 000 kWh per home. The cost to the utility was estimated at $0.2 per kWh saved (Nadel 1991).

Key issues surrounding loans are:

- zero-interest loans result in higher participation rates than low-interest loans;
- end-users, especially low-income groups, prefer grants to loans; and
- loans can be difficult to administer.

4.1.4 Leasing

There are many examples of leasing with regards to compact fluorescent lightbulbs (CFLs), two of which are described here.

In the United States, Taunton Municipal Lighting Plant, an electric utility, leases CFLs to their residential customers for $0.20 per month. If the lamp operates for three hours per day, monthly savings of $0.40 will be made - twice as much as the lease payments. The utility replaces broken or burnt-out lamps free of charge (Nadel et al n.d.).

In India, a similar leasing project (BELLE) was proposed by a consortium comprising the local electric utility, a major lighting manufacturer and a research institute as a pilot study for Bombay. Although the project failed to get off the ground as a result of institutional barriers, the proposal is an interesting one to review. The target residential population was risk-averse and cash poor and, therefore, most consumers were unwilling or unable to make the high initial investment for buying the CFLs. The lease arrangement was, therefore, considered an essential measure to overcome this first-cost sensitivity. For each CFL leased, the monthly charges would have been Rs 7.00 and the expected savings would have been Rs 106.00 per year. Another interesting aspect of this proposal was the consortium consideration of providing the CFLs free

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[6] In low-income programmes, however, strategies to promote energy efficiency improvements often result in higher equipment saturation levels owing to the low levels of energy service prior to implementation of the energy efficient policy. In such instances, the energy efficiency improvements fulfil equity considerations and are, therefore, not an undesirable outcome. This issue is, therefore, one of providing economically sound rebate structures, rather than one of conserving energy.

[7] In the latter years of the programme, interest was charged on loan amounts greater than $1,200.

for the first month as a measure to raise customer confidence in the savings and performance of the CFLs (Gadgil & Sastry 1992).

4.1.5 Direct installation

End-users may lack the time, money or expertise to install measures on their own and this may inhibit the implementation of energy efficiency improvements. Direct installation programmes attempt to minimise these barriers to end-user participation by providing comprehensive installation services to the customer. These services may include auditing and assistance both with the installation of energy efficiency measures and with their financing (Nadel et al n.d.).

Some markets do not respond to energy efficiency standards or the available technical expertise. Furthermore, owing to the political impediments to removing electricity price subsidies, conservation measures may not be cost-effective. Direct installation of energy conservation measures by electric utilities may be a viable alternative in these instances. The cost of the direct installation to the utilities can be reduced if some part of it can be recovered through electric bills (Dutt n.d).

In the United States, a number of electric utilities have sponsored direct installation programmes. The New England Electric System (NEES), for example, offers a programme for residential customers which provides and installs a variety of energy efficient measures including CFLs, water heater insulation and low-flow showerheads, all at no cost to the consumer. In order to reduce marketing costs, the programme is offered door-to-door, one block at a time. The benefits to the utility, in terms of lower construction and operating costs are, reportedly, far greater than the cost of the programme (Nadel et al n.d.).

The Bonneville Power Administration offers comprehensive weatherisation services to customers with electrically heated homes. The utility provides a free energy audit and arranges for private contractors to install certain low cost measures, such as insulation and energy efficient windows. Part of the cost of the measures is covered by a grant from the utility.

In Brazil, PROCEL, the national electricity conservation programme, operates a direct installation programme to replace incandescent street lights with mercury vapour and high pressure sodium lamps (Nadel et al n.d.). The programme is jointly funded by PROCEL and the distribution utilities, who stand to benefit from reducing arrears of defaulting townships. In 1986, the public lighting system had 1.2 million incandescent bulbs nationwide. Over half of these had been replaced by mercury vapour and sodium high pressure lamps by 1993 (De Araújo n.d.).

The advantages of direct installation programmes are that:

- they increase the penetration of energy efficient measures in the market by offering a comprehensive service which can include installation, auditing and financing; and
- the energy efficient products are installed by professionals which ensures that potential energy savings are maximised, for example, in the case of CFLs, this will ensure that they are installed in places where heavy use is made of lighting (Menanteau 1994).

4.1.6 Give-aways

In Europe, give-away lighting programmes resulted in the highest penetration rates out of all incentive options employed. They also resulted in the lowest societal costs of conserved energy (Mills 1991). These programmes traditionally target low-income groups and are generally most successful when community-based organisations are involved in the marketing of the CFLs (Nadel 1991).

4.1.7 Taxation schemes
Differential taxes levied on the sales/consumption of energy efficient products will tend to affect end-user choices among products. Tax differentiation can lead to relatively lower prices for energy efficient products. Differential taxes for different products, tend to bring about substitution among goods consumed rather than reductions in overall consumption levels, particularly when the demand for the basic class of goods affected has a relatively low elasticity (IEA 1989). In addition to the questionable effect of taxation schemes on behaviour, these schemes are associated with high administrative burdens.

In India, a number of different renewable energy and energy saving devices have been made exempt from sales tax (Nadel et al 1991). The effect of these exemptions on the purchase of the equipment is not documented.

4.1.8 Conclusions
International experience shows that different consumer groups respond to different types of incentives (Mills 1991). It is essential, therefore, that the programme incentive package is informed by the socio-economic circumstances and end-user preferences of the target group.

4.2 Manufacturer incentives
Negative regulatory practices and imperfect information inhibits the ability of producers to meet the potential market demand for energy efficient products. Manufacturer incentives aim to encourage the development and marketing of energy efficient equipment by overcoming these market barriers.

4.2.1 Voluntary agreements
Voluntary agreements between government and manufacturers to improve the efficiency of domestic appliances have been made in a number of countries. Two successful examples are in Germany and in Brazil.

German manufacturers entered into a voluntary agreement with their government to improve the energy efficiency of refrigerators and freezers by 15-20% between 1980 and 1985. The natural rate of improvement in efficiency as a result of competition is estimated to be about 2.5% per annum, amounting to a natural increase in efficiency of approximately 12% over the same period. Efficiency targets were, therefore, not set very high. German manufacturers, however, exceeded the performance targets substantially.

In Brazil, minimum efficiency levels were set for refrigerators through a process of consultation between manufacturers and government. These agreements required that by 1993, refrigerators in each category consume no more than the most efficient model available in 1989. Encouraged by the progress achieved, further agreements for more stringent efficiency standards have been proposed. These proposed agreements call for efficiency improvements of 5% per annum from 1994 to 1998, resulting in the 1998 models consuming only half as much electricity as those sold in 1990.

4.2.2 Technology procurement
Technology procurement can be defined as 'the process of a purchaser attempting to accelerate development in a desired direction by pledging future purchases of something that did not exist at the time' (Holm 1993: 3). Traditionally public authorities have been very active technology purchasers, for example in the defence and space industries, resulting in developments in civil technology. The purchaser negotiates projects which demand strict performance specifications and result in extensive development work together with the suppliers.

Technology procurement programmes give manufacturers incentives to produce new and more efficient products. When combined with consumer rebates on those products to encourage consumers to buy them, the market for the products is established and, therefore, manufacturers are encouraged to develop these products to meet the market demand. Incentives are provided by government or by a consortium of utilities to the manufacturer who successfully delivers a product meeting specified energy consumption and delivery date requirements (Levine et al 1992).

Traditional technology procurement has been concerned with satisfying a defined requirement by a completely new product.[8] The associated technical development was essentially regarded as a secondary, albeit desirable and valuable, effect. In more recent times, it has been the technical development, aimed at achieving more efficient designs, which has been considered the primary aim of the procurement process.

Market failure occurs because manufacturers have imperfect information about their customers in terms of what they want and how many there are. Technology procurement provides a solution, bringing together a number of important purchasers, drawing up performance requirements and offering the manufacturers substantial guaranteed orders if the requirements are met.

Technology procurement with the objective of achieving energy efficiency requires the creation of a market for these products. Demand in markets such as these is created by bringing together important customers and formalising and expressing their requirements (Nilsson 1993). The feasibility of effectively influencing the markets is influenced by the following:

- The role of the state should not be to purchase the products, but to define the requirements, to administer the project and to ensure market transformation.
- The technology procurement project should utilise the company's own development knowledge and facilities, providing the motivation and challenge for manufacturers to concentrate their resources into the development of new and better products. The government should thus not have to pay for product development.
- Support must not be aimed at individual producers, but rather at influencing the entire market. Support must rather be given to the purchaser to enable him/her to influence the supplier. If the purchasers' interests are gathered together to attract the interest of suppliers, the manufacturers' competitive abilities can be exploited to produce better products and more favourable prices.
- The best products on the market are to-date not sufficiently energy efficient and, therefore, if demand is sufficient to ensure adequately large volumes to cover costs, improvements in performance of the order of 10-20% can be effected. Technology procurement projects should, therefore, encourage purchasers not only to create a demand for the best products, but also to achieve more efficient products in the future.

In Sweden, NUTEK's Department of Energy Efficiency has been actively involved in employing technology procurement to influence technical development in the direction of more efficient use of energy. Technology procurement in Sweden has been applied to washing-machines and tumble dryers, lights and light fittings, refrigerators, windows and fans. The procedure used in these technology procurement programmes is to invite manufacturers to participate in a competition, where a reward is offered to the manufacturer who produces the best product over and above the performance specification.

Two examples of technology procurement programmes can be found in Sweden and the United States.

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[8] The definition of *product* in this context includes not only the good or service, but also the manufacturing processes involved in production.

In 1990, the Swedish National Board for Industrial and Technical Development (NUTEK), the National Council for Consumer Policies and representatives of 25% of apartment building housing associations announced a technology procurement project for electrically-efficient and environmentally-friendly refrigerators/freezers. Only those units which consumed less than 1.00 kWh/l per year would qualify for consideration for the competition and additional premiums were promised to all manufacturers who succeeded in reducing electricity use to less than 0.90 kWh/l per year. In addition, environmental requirements specified performance 'from cradle to grave', primarily with respect to CFCs in the thermal insulation and as a refrigerant. A third requirement was that low-energy units should be accompanied by clear and unambiguous details of their energy usage which will allow for easy comparison with other models. The prize offered was a guaranteed order for at least 500 units. Purchasers of these units were also encouraged by a promised subsidy of SEK 1 000 per unit. Electrolux won the competition with their refrigerator having an electricity demand of 30% less than the previously most electrically-efficient unit on the market and also containing considerably less CFC. Since then, a CFC-free model has come onto the market, the average electricity use by the market's ten best refrigerators has fallen by 20%, prices have dropped considerably and subsidies are no longer required (Holm 1993).

In 1992, 25 utilities in the United States announced a technology procurement programme for refrigerators, which is referred to as the *'Golden Carrot' Super-Efficient Refrigerator Programme*. Manufacturers were invited to produce a refrigerator that would use 30-50% less energy than the average American refrigerator, without using CFCs. Other requirements were that the price should be about the same as that for present day models and that certain production capacity specifications should be met. The prize was US$ 30 million, paid as US$ 100 per refrigerator sold. Fourteen manufacturers entered the competition, 12 of these being eliminated in the preliminary rounds. The final competition was a contest between Frigidaire and Whirlpool. The prize was awarded to Whirlpool. Frigidaire received no prize or award apart from the prestige of being selected for the final competition out of an initially large field and the value arising from the development work (Holm 1993). The programme intends to save consumers $240-480 million in annual electricity payments, which translates into electric bill savings of 10-35% for an average household (Greenpeace 1993b). It is important to note that many models have since surpassed the performance of the Whirlpool Golden Carrot Winner.

4.3 Energy supplier incentives

As mentioned in chapter two, traditional regulatory practices create a number of financial disincentives to utility investments in end-use energy efficiency improvements. Regulatory policies result in the situation where utilities are not allowed to recover the costs of their demand-side management practices from their customers, they are not allowed to earn profit from demand-side management practices and they lose profits with every unit of electricity saved (or gain profits with every unit of electricity sold) (Woolf & Mickle 1993).

Different types of utilities respond differently to these traditional regulatory policies. *Government-owned* utilities are not as strongly motivated by profit margins and, therefore, the question of lost revenue is not seen as a major issue. For example, in Thailand, EGAT, the government-owned utility is sponsoring the DSM pilot costs through the fuel adjustment clause (IIEC 1994b). Government-owned utilities do, however, have goals to recover costs and remain financially healthy and, therefore, would respond better to positive regulatory incentives. For example, public utilities in Europe have been slow to initiate activities which promote energy efficiency and, therefore, it is likely that they too require positive incentives (Mills 1991). *Investor-owned* utilities on the other hand are profit motivated and will, therefore, not consider demand-side management programmes that lower sales, unless the rate making process is modified (IIEC 1994b).

Positive financial incentives are necessary to ensure that utilities consider end-use energy efficiency investments as viable business alternatives to supply-side investments (Woolf & Mickle 1993). These supplier incentive schemes include:

- policies designed to allow utilities to recover the costs associated with their demand-side management practices, either by treating the cost of the DSM programme as an operating cost and allowing the full costs to be recovered during the year of expense or by treating the cost of the DSM programme as an asset and allowing the cost of the programme to be paid over time with an associated rate of return;
- shared savings, where the utilities are allowed to retain for their shareholders a predetermined portion of any savings realised through their demand-side management practices;
- policies which allow utilities to earn a bonus return from demand-side management practices; for example, utilities receive a higher rate of return on DSM investments than they would achieve if they invested in the supply-side (rate base premium) or utilities receive a bonus per unit of resource saved in excess of some nominal goal (performance premium); and
- policies which decouple profits and sales,[9] so that utilities are no longer penalised with lower revenues from DSM programmes and have no incentive to maximise electricity or gas sales (Woolf & Mickle 1993; IIEC 1994b; Sioshansi 1994). The most widely known decoupling mechanism is California's Electric Revenue Adjustment Mechanism (ERAM) (Moskowitz 1992). This mechanism is discussed in Box 4.3.

These financial mechanisms are not intended to pay utilities extra for their demand-side management practices, but rather to correct existing regulatory pricing schemes which do not accurately account for the financial implications of demand-side management (Woolf & Mickle 1993).

In 1982, the California Public Utilities Commission introduced a regulatory procedure called the Electric Revenue Adjustment Mechanism (ERAM) which aimed to reduce utility risk and improve the financial health of the industry as well as eliminate the perceived anti-conservation bias of previous Californian regulation (Marnay & Comnes 1992). ERAM allows utilities to balance accounts by adjusting for the over- or under-collection of authorised base revenues. Over- or under-collection is caused by discrepancies between actual and forecast sales of electricity. Utilities return these revenues to, or collect them from, customers through an adjustment in the price of electricity the following year.

BOX 4.3: California's ERAM experience

These incentives have generally been successful in motivating investor-owned utilities to take notice of end-use energy efficiency measures and many utilities in the United States are now relying on demand-side management for a growing share of their future energy and capacity needs (Sioshansi 1994).

There are a number of issues which have been raised around supplier incentive schemes. Sioshansi (1994) identifies these as the following:

- The type and level of the incentive is vitally important - incentives should be just large enough to make demand-side investments competitive with supply-side investments, rather than allowing utilities to reap large profits from their end-use energy efficiency investments.

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[9] *Decoupling* is the term used to describe 'a reform plan that breaks the linkage between profits and sales' (Moskowitz 1992:9).

- Non-participants have no veto power over what the utility does, how it selects and implements its demand-side management investments and which end-users it recruits for participating in the programmes, but they still have to pay the increased rates which result from the demand-side management programmes. Policy-makers must, therefore, select those measures and programmes where the societal benefits outweigh the costs to specific sectors in the society.
- Where financial rewards are dependent on the results of utility demand-side management programmes, exaggerated claims may result in utilities collecting too much money. These results must, therefore, be strictly evaluated.

5. Codes and Standards

Traditionally, performance standards have been used to promote higher-quality products and building construction, or to ensure health and safety performance levels, but they can also be designed to set minimum energy consumption levels, support the utilisation of energy saving products or materials and increase energy efficiency (Ontario Hydro 1991). These energy efficiency standards are specifications applied to the manufacture or sale of energy-using equipment or to the energy-related aspects of the construction of new buildings. Standards may be voluntary or they may be mandated by law. The development of standards requires research into prevailing manufacturing and construction practices and identification of technical options for more energy efficient products and building construction (Miller 1994).

5.1 Building codes and agreements

Building codes have a long history in terms of the application of health and safety precautions, but it is only in recent years that they have been applied to the thermal performance of the building structure. The primary goal of thermal performance building codes is to improve the efficiency of new building stock. They attempt to address market limitations such as invisibility of consumption, lack of information and separation of expenditure and benefit (IEA 1989).

Several countries have enacted mandatory building standards that include requirements designed to ensure that new buildings are energy efficient. Mandatory building codes occur in two forms:

- *Prescriptive codes,* which specify the particular equipment and materials that must be used in construction, as well as the design requirements. Such a building energy code was adopted in Singapore in 1979. Its success has been attributed to active enforcement of the code and builder incentives (Miller 1994).
- *Performance-based codes,* which give builders a choice of equipment and design as long as overall building energy use guidelines are adhered to. These are more difficult to monitor, but are gaining favour in the United States as they provide greater flexibility to builders.

Building codes have proved to be very effective in overcoming market limitations. They are a low-cost means of upgrading the thermal quality of new building stock. They are also easy to adapt to local and/or regional climatic conditions (IEA 1989).

The energy saving effects of building codes are likely to depend on the training of architects, builders and inspectors, as well as the enforcement procedures, and length of time the code has been in effect and its complexity (Nadel et al n.d.).

It is essential that building codes are revised regularly in order to keep up with technological improvements, and to encourage manufacturers and builders to keep improving on technology. Thermal regulations in France are a successful demonstration of regularly revised building codes. Building codes for the thermal properties of new residential structures were first instituted in France in 1974 and were revised in 1982 and again in 1988. As a result, the average specific energy consumption of housing units has been halved. Thermal standards will become more stringent in 1997 allowing further savings in heating needs (Ademe 1995). A labelling system which identifies thermally efficient buildings and a package of financial incentives to encourage the construction of buildings with higher energy performance levels than required by law were instituted in 1980. These two programmes reinforce the legislative efficiency standards, contributing to their success.

5.2 Minimum efficiency standards for appliances

Efficiency standards set a 'floor' beneath which the performance of new equipment can not fall. They do not, however, set a ceiling, since there are always techniques to exceed whatever efficiency level is mandated. They are generally designed to achieve the maximum improvement in energy efficiency which is technologically feasible and economically justified. Equipment efficiency standards will not generally lead to the development of a new technology, but may encourage the commercialisation of better technologies that are already available, and remove inefficient technologies from the marketplace (Geller & Nadel 1994). For this reason, minimum efficiency standards work better when implemented together with other types of programmes, such as education and incentive programmes. Incentive programmes can encourage energy users to demand equipment that is more energy efficient than is required by existing mandatory efficiency standards (Miller 1994).

The primary goal of appliance efficiency standards is to improve the efficiency of new appliances (IEA 1989). Like building codes, they address market limitations such as invisibility of consumption, lack of information and separation of expenditure and benefit, while encouraging manufacturers to improve the efficiency of their products.

Under the auspices of PROCEL, the Brazilian government has entered into an efficiency protocol with the manufacturers of certain appliances (Nadel et al n.d.). This has resulted in the establishment of a set of proposed voluntary standards to cover refrigerators, freezers and lighting products. The refrigerator and freezer standard would require that by 1993 all new models match the efficiency of the best 1990 model and subsequently improve 5% per year from 1994 to 1998 (Miller 1994).

Efficiency standards have been implemented for all appliances sold in Taiwan. All efficiency standards are mandatory and no product is allowed to enter the market or be imported unless it meets the minimum standards (Hsueh 1992). This has been extremely successful in encouraging Taiwanese manufacturers to improve the efficiency of air-conditioners, and great energy savings have been experienced since the implementation of the appliance efficiency standards in 1981. The mandatory standards applied to smaller appliances, such as fans, ovens and so on, have been less successful. It has proved difficult to enforce these standards and, therefore, great costs have been incurred. Large numbers of producers apply to have their products tested and this requires substantial human and financial resources to effect. Policing and seizing of products which have not been tested absorbs funds. These regulations have proved to be unenforceable and, therefore, they contribute to the degrading of the trustworthiness of the government's ability to enforce its own regulations. It has been recommended that the standards for this class of products need to be made voluntary, because the savings in energy resulting from the regulation of these small appliances is relatively small and because the standards are difficult to enforce. From this experience, Hsueh (1992) argues that if the cost of enforcement is considered, then efficiency standards should be made mandatory only for large appliances, such as refrigerators and air conditioners. Voluntary standards, combined with information and educational programmes with respect to appliance energy efficiency, can be applied to smaller appliances as a means to encourage the market penetration of energy efficient appliances.

In the United States, appliance efficiency has been targeted by the State. Performance standards for new appliances were set up by the DoE under the National Appliance Energy Conservation

Act of 1987 and expanded as part of the Energy Policy Act of 1992 (Greenpeace 1993b). These efficiency standards are updated every four to five years to reflect the improvements in technology. The DoE devises tests to determine what sort of improvements are technically possible and economically feasible. It considers the impact on manufacturers and end-users, as well as the potential savings in energy and operating costs to determine what sort of improvements should be made. Appliance performance standards are applied to a wide range of products in the United States. These include refrigerators and freezers, air conditioners, furnaces, clothes-washers and dryers, heating equipment, fluorescent lamps, cookers and televisions. While standards have resulted in huge improvements, the capital costs to consumers have increased by very little. For example, the standards for refrigerators in 1993 have resulted in a 30% improvement on the 1990 standard, while end-users capital costs have increased by only 1% (Greenpeace 1993b). The success of this programme has been phenomenal. The standards generated a US$1 000 return in energy savings for every US$1 spent by the federal government. Furthermore, the appliance efficiency standards adopted to-date will save end-users US$132 billion over the life of the products covered and avoid the need for 58 000 Megawatts of new capacity (Freedman 1995). Despite this success, in July 1995, the United States federal government voted to eliminate funding for the DoE's building codes and energy efficiency standards programmes, cutting the budget by US$12.8 million.

5.3 Conclusions

The following draws out the key elements with regard to the development of codes and standards:

- *Performance-based* versus *prescriptive* standards:

  Experience shows that performance-based standards are preferable to prescriptive standards because they are flexible, stimulating rather than inhibiting technological innovation (Geller & Nadel 1994).

- *Voluntary* versus *mandatory* standards:

  Arguments for voluntary standards are that negotiation yields better results than force, and creates the basis for long-lasting cooperation between administration and producers; voluntary standards are more flexible; standards may require less control if they are negotiated; and mandatory standards can hinder the free passage of goods if they are applied to one country only[10] (Lapillonne 1993). Voluntary standards are, however, limited by the fact that they cannot be enforced by government and, therefore, they need to be accompanied by incentive programmes to encourage their adoption. Furthermore, the political consensus required for voluntary standards can take a long time to achieve as it requires agreement between government, environmental groups and manufacturers, who have very different interests and agendas (Levine et al 1992).

  Mandatory energy efficiency standards set minimum defined performance improvements within predetermined time-scales, enabling a more reliable estimation of the outcome. This results in product development being forced to occur at a faster pace than would otherwise have occurred, leading to enhanced competitiveness. Mandatory standards do, however, require an adequate enforcing system, and this enforcement and implementation requires authority and expertise.

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[10] This is dependent on which market is being target for appliance penetration. The energy efficiency of the product can certainly improve the competitiveness of the product in certain markets. For example, the high levels of energy efficiency of American refrigerators is viewed as a competitive advantage for American manufacturers wishing to enter the European market.

Lapillonne (1993) states that mandatory performance standards should be applied to building regulations, whereas voluntary standards should apply to appliances,[11] because in terms of international competitiveness, it is more difficult to apply national standards for appliances than for buildings. This point of view explains the philosophy behind the approach of seeking international agreements and working with voluntary standards. Hsueh (1992) argues that, while mandatory performance standards should be applied to buildings and larger appliances, such as refrigerators and air-conditioners, which accrue large savings, voluntary standards should be applied to smaller appliances, where the savings do not justify the expenditure on enforcement. Geller and Nadel (1994) reinforce this argument, stating that mandatory standards should be applied to selective products and energy efficiency measures.

The costs of these programmes to the government vary from zero to moderate, with voluntary standards incurring zero costs and mandatory standards incurring moderate costs associated with enforcement and implementation of the programme.

- The standard must be defined and measured in terms of an appropriate measure of performance. This requires the development of test procedures and adequate testing facilities. Internationally accepted test procedures are available from the International Standards Organisation.
- The building code or equipment standard must be designed to require an appropriate level of efficiency. The proper level of efficiency will take into account the technical feasibility and costs and benefits to consumers and society. Problems of substitution of imported products for domestic products arise when the performance level is set too high and when overly aggressive standards make it impossible for manufacturers to achieve the required level of performance in the allotted time frame.
- Product standards must be preceded by effective product test programmes. Product testing is necessary to determine efficiency levels in available products. It should be standardised to ensure that the efficiency savings are clear and unambiguous. The testing should be carried out by organisations that are beyond reproach and do not have an interest in the outcome of the tests (Miller 1994). With results from standardised testing, minimum efficiency standards and economic incentive programmes can be implemented. Product testing can also be used to support an efficiency labelling programme.
- Performance-based standards should be updated and strengthened periodically to ensure that technological advancement in energy efficiency continues to be made (Geller & Nadel 1994).
- The impact of the standards vary according to their stringency (IEA 1989).
- Appliance standards have been proven to be an effective method for reducing both actual and expected growth in electricity use in both industrialised and developing countries (Levine et al 1992).

6. Price restructuring

As mentioned in Chapter Two, electricity has often been priced below its long-run marginal cost curve, and often below its short-run marginal cost curve for household end-users. Owing to consumer expectations and political compulsions, it has sometimes been difficult to increase these electricity tariffs. This low price of electricity hampers the introduction of energy efficient technologies (Sathaye & Gadgil 1992).

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[11] This statement excludes health and safety standards, which should be applied to all products.

Furthermore, in many countries, electricity prices do not even reflect the full cost of producing and distributing electricity. Where utilities are subsidised by government, as in many developing countries, the price of electricity tends to be below the cost of supplying electricity to the end-user. In this case, the burden is placed on the government to make good the financial losses incurred by the country and to provide finances for the expansion required to meet the growing demand for electricity (Natarajan 1991).

It is vitally important that the correct pricing signals are given so that energy decision-makers (state, architects, designers, landlords and owners/occupants) can make informed decisions about the cost-effectiveness of energy efficient technologies. However, average electricity prices and prices to individual end-user classes continue be lower than optimal, and declining block rates[12] and promotional tariffs to encourage increased use of electricity for specific uses, for example industry, persist in some utilities. Thus, electricity price reform - affecting both the total price and the structure of electricity prices - can have a significant effect on end-use efficiency (Levine et al 1992).

6.1 Total price

Experience has demonstrated that in many cases it is ill-advised to change prices to cost-based levels too quickly. For example, in Jamaica, Ecuador, Mexico and Guatemala, price increases led to protests, contributing to civil disorder and even a change in government. In Poland, increases in the price of electricity resulted in the increase in the price of input fuels (coal), which in turn has been attributed as the cause of the ensuing accelerating rate of inflation (Levine et al 1992).

Electricity prices are crucial to the achievement of energy efficiency improvements because, without the correct pricing signals, energy efficient measures are likely to be cost-ineffective, particularly for the poor. The effect of increased prices on consumption is determined by the price elasticity of demand. One estimate suggests that the long-run price elasticity of demand for electricity can be as high as -1, varying significantly between countries (Levine et al 1992: 63). This implies that if electricity prices rise, for example, by 30%, total demand for electricity will fall by 30%. Many analysts consider this estimate to be high by a factor of two, but it serves to illustrate the importance of proper electricity pricing signals to the allocation and use of energy.

Natarajan (1991) states that although it is essential that utilities price energy according to the long-run marginal costs associated with its production, distribution and consumption, when one takes into account the social and regulatory requirements of electricity pricing, departures from long-run marginal cost-based tariffs are needed.

6.2 Time-of-use (TOU)

Time-of-use (TOU) rates are cost-based electricity prices which include temporal considerations. These prices, which reflect changes in costs of supply over time (peak hours, daily and seasonal), generally result in the most efficient allocation of resources. Furthermore, TOU rates can reduce the costs of electricity by shifting use from periods of high-cost to periods of low-cost power, thus flattening the energy load profile (Levine et al 1992).

The demand for electricity is higher during the day than at night and higher in winter than in summer. Since electricity cannot be stored, power stations have to be brought on and off line as required to meet these fluctuations in demand. This influences the costs of energy supply. Natarajan (1991) elaborates on this further with the following statement:

> The cost of generating electricity is purely dependent on the combination of power stations that are used at a given point of time to generate the required amount of power.

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[12] Declining block rates are a price structuring system in which electricity prices decrease at higher levels of consumption, thus encouraging increased consumption.

> This combination of power stations decides the cost of supply; hence ... consumers must be given a signal as to the true cost of electricity supply at different hours of the day.

Uniform electricity prices for all consumer categories at all times fail to provide the correct signals for energy decision-makers, because they do not reflect the changes in the cost of supply of the energy service. TOU rates aim to correct this situation by giving a different value to electricity at different times of the day and/or in different seasons. Utilities typically bill their customers at lower rates during nighttime, weekends, holidays and summer (off-peak periods) and bill their customers at higher rates during daytime, workdays and winter (peak periods). In this way, TOU rates encourage end-users to shift electricity use to off-peak times, reducing electricity use at peak times and scheduling new electricity uses away from high-use periods. TOU rates are thus used to flatten electricity demand, thereby using generating stations more economically and reducing the need for more generating capacity. Although TOU rates have typically been applied to industry, some utilities have offered the TOU rate structure to residential customers on a mandatory or voluntary basis. The TOU rates not only benefit the utilities, but also customers who can save money by planning electricity use during off-peak hours to take advantage of the cheaper rates (Ontario Hydro 1991).

An electric utility, Ontario Hydro, conducted a study to determine the effect of TOU rates on residential customers electricity-use patterns. Meters were installed in 500 residential homes to record energy use every 15 minutes over a period of five years. A variety of rate structures and TOU periods were used to determine what combination delivered the best results. The result was a 6% shift in electricity consumption away from peak times of the day (Ontario Hydro 1991).

An American utility, PG&E, offers not only different rates for electricity on a daily basis, but also different rates for electricity seasonally. Electricity, therefore, costs significantly less in off-peak hours and TOU rates are even lower in the summer season. The TOU rates are reinforced by information programmes. Brochures are distributed to utility customers, containing information about what TOU rates are, when off-peak and peak periods are, how to read a TOU electric bill and how the end-user can shift their energy use to save money. A telephone service which answers customer questions about how to save energy is also offered. In addition, disaggregated bills are issued to utility customers so that they can see how much of their energy consumption took place during on-peak and off-peak hours, what the different rates are for the two use categories, the total amount of electricity used in that month as compared to the total amount used during the same month in the previous year, the total amount of energy used and the total amount due to the utility for the energy service (PG&E 1993a).

6.3 Interruptible loads

Interruptible and curtailable tariffs permit the utility to meet higher energy requirements with reduced capacity and can save substantial costs for both the end-user and the utility (Levine et al 1992). They are a further measure by which utilities can defer the need for new generating supply and help to ensure the reliability of electricity supply during high-use periods. The principle behind this is that end-users who are large users of electricity can contract for all or part of their electricity at a cheaper rate on condition that they agree to do without power on request of the utility. Requests to cut the interruptible load are made when the utility is having difficulty meeting customer needs. This strategy may not result in a decrease in overall electricity energy use since the end-users may simply reschedule operations to a later date, but it does reduce the use of energy at peak consumption times.

Although interruptible rates have traditionally been offered to large commercial and industrial customers, some programmes have also been applied to residential customers. In the United States, utilities pay customers a monthly fee in exchange for the right to turn off air conditioners, water heaters and other residential appliances for a limited number of hours at times of peak electrical demand. The utility usually attaches a radio control unit to each appliance in the programme. When load reductions are needed, the utility operates the radio control, switching off the appliances without action being required from the end-user (Nadel et al n.d.).

6.4 Increasing block rates

Increasing block rates exist where prices increase at high levels of electricity usage. They are, therefore, capable of sending pricing signals which are consistent with long-run marginal cost curves. Furthermore, the initial block can be designed so that energy is affordable to low-income users and the upper blocks can be designed to penalise high energy users (Levine et al 1992). In this way, cross-subsidisation from rich to poor households can occur. In Brazil, inclining block rates have been implemented for low-voltage consumers. Residential rates rise when demand exceeds 30 kWh/month, 200 kWh/month and 500 kWh/month. This type of rate may not be consistent with the cost of service-based rates, but it can be a powerful incentive for conservation (Nadel et al n.d.). The pitfalls with this form of tariff structure are that: firstly, it deliberately fails to allocate costs *equitably*;[13] secondly, it is complex which may lead to confusion among end-users; and thirdly, international experience has shown that increasing block rates fall foul of political pressure, resulting in an increase in the size, or a decrease in the rate, of the low rate block over time (Pickering 1994).

6.5 Flat rate tariffs

The flat rate tariff, or single energy rate tariff, is generally designed so that the *average* consumer would pay the full cost of supply each month. Households consuming less than the average number of units per month would thus be subsidised by some amount, while consumers using more than the average number of units would pay an additional amount above the actual cost of supply. The flat rate tariff is simple to both implement and understand (Pickering 1994).

7. Finance

There are four main sets of institutions responsible for financing energy-efficiency strategies and programmes. These are government, utilities, banks and international assistance agencies and will be discussed in more detail below.

7.1 Government

An example of government-sponsored financing can be found in India. Several different energy efficiency programmes are operated by its three national development banks. These programmes generally combine subsidised energy audits provided by private engineering firms with concessional rate loans. The interest rates generally range from 1-4% below conventional development bank loans. As of March 1990, the largest of the three programmes had provided financing for 122 energy audits and had committed approximately $13 million in loans for energy saving equipment (Nadel et al n.d.).

Not all financing programmes in developing countries are based on loans. For example, in the People's Republic of China, the Energy Conservation Company (ECC) of the State Energy Investment Corporation provides grants which normally cover one-third of the project's cost. Some additional funds come from federal ministries or local and provincial governments, but the bulk of the funds comes from the individual companies making the energy-saving improvements. The ECC has annual budget of about $300 million of which some goes to proven technologies and some goes to demonstrating new technologies (Nadel et al n.d.).

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[13] Here equity refers to cost-reflective equity, rather than broader equity goals that would include positive redistribution.

7.2 Utilities

Utilities are good financing sources for energy efficiency investments because they have access to large amounts of capital and they have ongoing financial relationships with energy end-users. Utility financing is most cost-effective for large loans and for investments in equipment that is substantially more expensive than their less efficient counterparts. Loans can be provided at market or subsidised rates, although energy efficiency financing is more likely to be successful if funds are provided at attractive rates, participation is convenient and technical assistance is offered (Nadel et al n.d.).

In Canada, Ontario Hydro, an electricity utility, offers the Power Savers Loan Plan to residential customers. The aim of the plan is to help homeowners to manage the costs of improving energy efficiency, by lowering the cost of energy efficient products. The motivation for this is that residential customers are discouraged by high installation costs when attempting to increase the energy and electricity efficiency of their homes and will, therefore, often not make the energy efficiency improvements. The Power Savers Loan Plan is a financing package to facilitate home energy improvements. It features a 24-hour loan approval and flexible terms and competitive rates. The loan is initiated by registered contractors and administered through a major chartered bank. Over 3 200 contractors are registered under the plan. Designated energy efficient products such as insulation carry a below-prime interest rate, while other products such as central air conditioning and windows are also covered on the loan plan, but at higher interest rates. The loan scheme has been successful, with more than 4 000 loans being initiated in 1989 and 1990 for over $16 million (Ontario Hydro 1991).

7.3 Banks

Governments and utilities can enter into agreements with commercial banks to secure favourable loans for energy efficiency investments. Suggestions have been made to change the rules for lending money for home building, so that only the most efficient technologies qualify for these loans. Potential problems arising out of this strategy would be that such an alteration in the conditions for granting loans could create an added burden for low-income population groups, inhibiting their access to loans. An alternative suggestion is to create a framework which allows for the consideration of the operating costs of appliances and houses during the loan approval process (Schipper & Hawk 1989). This would entail assessing the eligibility of the loan application in terms of the operating costs and offering favourable rates for energy efficient investments.

7.4 International assistance agencies

7.4.1 Multilateral Development Banks[14]

The multilateral development banks include the International Bank for Reconstruction and Development (World Bank), the Asian Development Bank (ADB), the Inter-American Development Bank (IDB), the African Development Bank (AfDB), and the European Bank for Reconstruction and Development, which focuses on Eastern Europe. A further example would be the International Finance Corporation (IFC), a World Bank affiliate which combines the characteristics of a multilateral development institution and a private merchant bank and is responsible for assisting private sector enterprises. The multilateral development banks' energy investments average between $5 and $6 billion per annum[15] and are thus the most important source of capital for energy investments in developing countries. They are also significant in that they shape energy development and consumption in developing countries through their

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[14] This section is based on two text sources: Michael Philips (1991) and Peter du Pont (1994).

[15] Of this, approximately $3-4 billion was provided by the World Bank, $1 billion by the IDB, $600 million by the ADB and $250 million by the AfDB.

economic advice, their loan conditions and their investments in the energy production and consumption sectors. Furthermore, owing to their global authority, they influence the investment priorities of bilateral and multilateral assistance agencies, commercial banks and other investors.

Despite the fact that end-use energy efficiency investments are often argued to produce more energy per dollar than investments in new energy supply and are consistent with the banks' goals of encouraging economic efficiency and improving foreign exchange balances, less than one percent of the banks' energy lending goes toward improving end-use energy efficiency. The reasons for this low investment in energy efficiency are the following:

- there is pressure, within the multilateral development banks, to meet annual lending targets, militating against small loans like those generally involved in energy efficiency projects;
- many developing countries are uncertain of the benefits of energy efficiency and are, therefore, reluctant to borrow for the purpose of energy conservation; and
- the banks' lending staff generally overlook energy efficiency as a strategy because they lack the experience to implement energy efficiency projects and they do not consider energy efficiency to be relevant to the macroeconomic circumstances of developing countries.

This has limited the multilateral development banks' activities in end-use energy efficiency, which have, therefore, consisted mainly of providing broad studies of whole countries' energy use and some audits of energy efficiency opportunities in specific facilities. However, all of the banks have urged developing countries to adopt 'economic' energy pricing, with prices high enough that energy users' payments for energy cover the costs of supplying it. This is one strategy which leads to higher investment in energy efficient options.

The Asian Development Bank (ADB) has taken the lead in terms of its support for energy efficiency and renewable energy sources. In February 1994, ADB's Energy and Industry Department submitted a draft energy policy entitled 'Bank Policy Initiatives for the Energy Sector' to the ADB's Board of Directors. The draft policy defines appropriate energy sector goals for the developing member countries; it calls for the improvement of energy efficiency in production, transport and end-use of energy and it emphasises the integration of environmental considerations into energy sector activities. It outlines the bank's commitment to providing technical support for demand-side management and integrated resource planning efforts by developing member countries and it requires that developing member countries show that they have at least considered demand-side options when applying for power sector loans. A parallel commitment stated in the draft policy document of the ADB is to provide for 'basic human energy needs', thus supporting both development and energy efficiency. A comparison of loans and technical assistance grants in 1990 and 1994 shows that the amount of technical assistance funds going to energy efficiency and renewable energy has increased significantly. This indicates that some support is given to the Bank's draft policy at the operational level.

7.4.2 Global Environmental Facility (GEF)[16]

The Global Environmental Facility (GEF) is a source of funding for global environmental actions. Its purpose is to provide new and additional financial resources for the 'agreed incremental costs of measures to achieve agreed global environmental benefits in four specified focal areas' (GEF 1995:1) - climate change, biological diversity, international waters and ozone layer depletion. Programmes which are eligible for funding are those which are country-driven and based on national priorities designed to support sustainable development. The GEF serves as a funding mechanism for agreed global environmental conventions and is presently operating as

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[16] This section is based on two text sources: Bergesen & Parmann (1995) and Global Environment Facility (1995).

an interim financial mechanism for the implementation of the Framework Convention on Climate Change and the Convention for Biological Diversity. Ratification of these treaties is thus a prerequisite for eligibility for funding.

The GEF receives its funds in the form of grants from donors, which include both developed and developing countries. In 1995, 26 countries announced pledges to the GEF, including eight developing countries. The main contributors are the USA, Japan, Germany and France, who have pledged to provide 63% of the Facility's funding for the period of 1994 to 1997.

The concept of *incremental cost*[17] is pivotal in GEF. The reasons for this are that financing the incremental costs from new and additional sources results, firstly, in scarce funds being dedicated to achieving global environmental benefits rather than achieving development and local environmental benefits, for which other sources of funds are appropriate and, secondly, in eligible countries not having to divert scarce development finance to achieve global objectives nor give up their national development goals to do so.

The financing modalities offered by the GEF are:

- *grants*, which come in the form of either an initial lump sum which is paid up front or in instalments as and when incremental costs occur;
- *concessional finance* in the form of either a one-off repayable loan at a below-market interest rate or a revolving fund for activities of a specified type. Such finance is awarded to economically unattractive projects that would protect the global environment and to measures that are financially constrained even after a grant has been made for incremental cost; and
- *contingent finance*, that is a loan which is normally repayable, but all or part may be forgiven (that is, turned into a grant) under specified contingencies. Such contingencies include technical and institutional risks which may make the project unsuccessful. Part of the loan would, therefore, be converted into a grant for the incremental costs actually incurred.

One of the problems associated with incremental cost funding is that where measures that protect the global environment are economic even in the absence of global environmental considerations and, therefore, have negative incremental costs, they are not eligible for GEF grant support. This proposes a problem when capital constraints prevent these measures from being implemented.

8. Institutions

Energy efficiency issues require a coordinated effort in order to ensure a high degree of integration between the different energy use sectors, thus facilitating the development and implementation of an integrated energy planning approach. It is sometimes suggested that this requires a central organisation to coordinate energy-conservation activities. Such an organisation might be a government agency, a privately constituted group or a public-private combination. It could serve as a intermediary body to channel energy-conservation loans from the multilateral development banks to large numbers of dispersed users who are in a position to effect energy efficiency strategies (Jackson 1992).

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[17] Incremental costs are defined as those additional costs incurred by the national action required to realise global environmental benefits beyond the costs that are strictly necessary for achieving the country's own development goals. The GEF finances the difference between these costs to relieve 'the future economic burden on the country that would result from its choosing the GEF supported activity in preference to one that would have been sufficient in the national interest' (GEF 1995:4).

Such central organisations have been set up or proposed in a number of different countries as a means of coordinating national demand-side management programmes. In Thailand, for example, the three state owned utilities - the Electricity Generating Authority of Thailand (EGAT), the Metropolitan Electricity Authority (MEA) and the Provincial Electricity Authority (PEA) - have jointly formed the *Demand Side Management Office*, a centralised organisation which functions as a coordinator of a nationwide financial incentive programme which aims to promote the construction of energy efficient new buildings, and the use of energy efficient equipment and appliances in homes. The DSM office consists of three major units - the Program Design and Delivery Team, the Planning and Evaluation Team and the Technology Assessment Team - which work together to develop, implement, market and evaluate DSM programmes nationally (IIEC 1991).

A further example can be found in Brazil's national energy conservation programme, PROCEL. The GCCE (Coordinating Group for Electricity Conservation) was created to coordinate the measures and projects submitted to PROCEL through four committees - Consumption and Consumers, Legislation, Tariffs and Incentives and Technology Development. Representatives from the government, from state enterprises, utilities and private business sit on the GCCE, while the actual operation of the programme is the function of the Secretariat of the GCCE (De Araújo et al n.d.).

CHAPTER FIVE

Lessons for South Africa

5.1. Introduction

Historically, international energy planning has been supply-oriented. Inherent incentives encouraged (and in many countries, continue to encourage) utilities to maximise sales and capacity, and to increase their revenues by encouraging consumption and expanding their market. The oil crisis of the 1970s resulted in a change in international philosophy toward the supply of energy. Profits and sales have, in many cases, been delinked and many utilities have adopted integrated resource planning.[1] This has resulted in the proliferation of a number of demand-side management (DSM) strategies and the promotion of energy end-use efficiency as the 'fifth fuel'. In South Africa, Eskom has been reluctant to catch on to this new wave of energy planning. While Eskom has recently developed a residential demand side management (RDSM) programme, it continues to see itself as a supplier of electricity with the aim of maximising sales, as opposed to a provider of energy services.

With the Reconstruction and Development Programme's housing strategy and the national electrification drive, demand for electricity will continue to rise and electricity capacity will be over-stretched. Thus, there is an urgent need for South Africa to adopt integrated energy planning and demand-side management strategies which benefit not only the utilities by reducing their need to create new generation capacity, but also the end-users. Energy efficiency policies and programmes can reduce or shift energy consumption and, therefore, have the potential to reduce the energy costs of households, thus displaying equity benefits as they release household financial resources for other purposes and as they increase access to energy services.

Integrated energy planning (IEP) and DSM have been practised in industrialised countries since the 1970s, and more recently in developing countries. Many different energy efficiency strategies have been tried and tested, bearing varying degrees of success. South Africa can benefit by studying these international energy efficiency programmes and policies and learning from past failures and successes.

5.2. Who should initiate DSM strategies?

The implementation of RDSM programmes in South Africa has occurred in a limited way by electricity distributors - Eskom and to a lesser degree the local authorities. Eskom's RDSM plan aims to 'structure, direct and coordinate residential demand side management (RDSM) programme development efforts [in order] to sustain the decrease in the real price of electricity in the long term, to increase electricity's competitiveness in the small customer energy market and to contribute towards environmental conservation and awareness' (Naudé & Lane 1995:4). Eskom has identified five main programmes for implementation in the residential sector. These are time-of-use tariffs, water-heating load management, appliance labelling, efficient lighting, and thermal comfort. Only two of these programmes - TOU tariffs and water heating load management - have been initiated so far.

International debates surrounding the implementation of DSM initiatives have questioned the effectiveness of utilities as initiators and executors of energy efficiency programmes. It is argued that utilities do not always deliver the best and cheapest energy conservation because they give preference to investments which are in their own interest, not those which are socially optimal. It is also suggested that, under current regulations, utilities do not have sufficient incentives to engage in genuine energy efficiency. Evidence for this argument can be found in the utility-dominated DSM programmes in South Africa. While Eskom's RDSM programme does address issues of energy affordability and environmental conservation, the motivations behind it are supply dominated. The main focus of the programme is to decrease real prices so as to increase sales. Eskom thus continues

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[1] Integrated resource planning involves the provision of energy services at the lowest cost to society by a balanced assessment of both demand- and supply-side resources.

to be driven by profit rather than social or environmental concern. If utilities are not the best institutions to implement energy efficiency improvements, then who are? It can be argued that no one set of institutions is the most appropriate. Rather a collaboration between different sets of institutions, each performing that role which they fulfil most efficiently and effectively, is the way to provide energy efficiency improvements at the least cost. Furthermore, only if all parties are involved can one hope to achieve energy efficiency improvements within an integrated energy planning framework.

The roles that government should take on are to stimulate the development of energy efficiency equipment through the funding of research and development, and to stimulate the penetration of energy efficiency technology on the market in its capacity as a big purchaser (Olerup 1995). Furthermore, government can facilitate utility and end-user involvement by removing disincentives such as low energy prices and by delinking electricity sales and utility profits. Under the right regulatory conditions, utilities have a significant role to play in DSM activities. Utilities have a direct relationship with the end-user, placing them in a unique position to offer and promote energy-efficient strategies and financial packages to their customers. ESCOs have the potential to offer support to both utilities and end-users, providing skills, arranging financing and absorbing risk, thus helping to overcome barriers of entry into the energy efficiency market.

5.3. Why do we need policy?

There are a number of financial, economic, behavioural and technological barriers to the implementation of measures to increase end-use energy efficiency. These include market failures (such as lack of information, split incentives and price distortions), government regulatory practices, first-cost sensitivity and lack of finance. Thus, it is necessary to implement conservation measures and strategies to overcome these barriers. In order to effectively implement these energy efficiency policies and programmes, coordinated action is required between government, utilities and third party companies.

There is often reluctance for government to intervene in the market place, but intervention to effect energy end-use efficiency can be justified. There are two main ways in which it has been justified in the past. These are:

- Support for DSM initiatives through market intervention has been justified as a *public policy choice*, which is largely tied to a concern for environmental protection and intergenerational equity (Haaland 1995). Economic efficiency and intragenerational equity are considered to be less significant than concerns for the environment.
- Market intervention has been justified on the grounds that *market failures*, such as price distortions and split incentives, make energy efficiency less economically viable. Thus, energy efficiency interventions may be viewed as a means of correcting market distortions and allowing for an efficient allocation of resources.

The motivations for adopting end-use energy efficiency vary between countries and the types of strategies employed are dependent on the political priorities of the government and, in particular, the socio-economic status of the end-users. Concerns for the environment, equity, economic development and energy security have all featured as motivations for implementing energy efficiency strategies. In South Africa, at present, the Reconstruction and Development Programme (RDP) is driving the political process and, therefore, it is essential that energy efficiency programmes are not driven by environmental concerns alone, but also fulfil its objectives. Such programmes in South Africa must fulfil national objectives of social upliftment, job creation, capacity building and improved equity and access to services.

In South Africa, a large sector of the population has poor energy services. Energy efficiency strategies may allow for the fulfilment of those previously unfulfilled energy service needs. Thus, energy efficiency can be considered as a strategy to effect greater equity and development. Timeous intervention is extremely important. South Africa is poised to commence delivering housing to its low-income citizens and is also currently pursuing a massive electrification drive. It is essential that energy efficiency programmes are implemented now while national and provincial policy can still be influenced and so that the potentially greater costs associated with retrofitting are avoided.

5.4. Policy options

To exploit energy efficiency to the full, an effective framework is needed to achieve the right balance between regulatory instruments (for example, minimum efficiency standards for buildings and appliances) and market-based instruments (for example, financial incentives). Education and awareness-raising initiatives need to be run simultaneously to promote and enhance the effectiveness of these incentive and regulatory programmes (Collins 1991). This report forms part of a three-year policy-oriented energy efficiency research project which aims to develop energy efficiency/DSM strategies for the residential sector in South Africa. Without pre-empting that, it is possible to distil a number of lessons from international experience. The policy options considered relate to four main areas - price restructuring, thermal performance of housing, appliance efficiency and fuel choice. These areas have been identified as the most appropriate to the South African context because of the opportunities afforded by the RDP for immediate implementation of such strategies and/or because they are considered a necessary component of a national residential DSM programme.

5.4.1 Price restructuring

Electricity prices in developing countries have historically served economic development, with artificially low prices promoting the development process (Levine et al 1992). Energy prices have seldom reflected the social, environmental and full economic costs of generation, distribution and consumption and, consequently, market failures have occurred, resulting in the misallocation of resources. There is a real danger in South Africa that electricity prices will continue to be kept low to effect both economic and social development, thus encouraging excessive energy consumption. Cost-reflective energy pricing signals are important for the efficient allocation and use of the resource. Without the correct pricing signals, it is impossible to create an environment in which energy efficiency policies and programmes can work. Thus, it is important that the electricity pricing structure is adjusted to generate the right signals to end-users, manufacturers and government in South Africa.

Electricity price reform can be effected in two ways. Firstly, through adjusting total cost to reflect the real costs of providing the energy service and, secondly, through altering the tariff structures to reflect the temporal differences in costs of energy provision and/or to penalise those with high consumption levels.

5.4.1.1 Increase electricity price

Higher energy prices motivate energy efficiency actions; when energy prices are stable and low, it takes much more effort to sell the concept of energy efficiency (Sioshansi 1994). Energy prices need to be restructured to reflect the real costs of providing the energy services. This will give the right signals to energy decision-makers, encouraging the adoption of end-use energy efficiency measures and stimulating the development of energy efficiency technologies.

Experience has demonstrated that in many cases it is ill-advised to change prices to cost-based levels too quickly. Price increases have led to protests, civil disorder and even changes in government. When raising energy prices, it is vital that the socio-economic profile of the country's population is taken into consideration. Many of the poor do not yet have access to cost-effective and convenient energy services and it is essential that any policies adopted to improve energy pricing signals, do not exclude the poor from attaining these services. Therefore, when adjusting the electricity pricing system to reflect real costs, the reforms must be phased over an appropriate period of time and the energy efficient strategies must be in place to relieve the poor of the burden of increased prices and to ensure that their access to this service is not further restricted.

An easier and more effective method of adjusting pricing structures to ensure a more efficient allocation of resources is to alter the tariff structure for energy provision. The most common methods proposed to control household energy consumption are time-of-use rates, increasing block rates and flat rate tariffs. Interruptible rates have also been introduced for household electricity consumption in some cases.

5.4.1.2 Restructure tariff rates

Residential interruptible rates require substantial involvement from utilities. Fitting of radio control units to each appliance in the programme is potentially expensive and complex and, therefore, unsuitable for South Africa.

Time-of-use (TOU) rates are cost-based electricity prices which include temporal considerations. The principle is that end-users are billed at lower rates during nighttime, weekends, holidays and summer (off-peak periods) and at higher rates during daytime, work days and winter (peak periods). The motivation for this is that demand for electricity is higher through the day than at night and higher in winter than in summer. Since electricity cannot be stored,[2] power stations have to be brought on- and off-line as required to meet these fluctuations in demand. The aim of TOU rates is to encourage end-users to shift electricity use to off-peak times, reducing electricity use at peak times and scheduling new electricity uses away from high-use periods. In this way TOU rates are used to flatten electricity demand, using generating stations more efficiently and reducing the need for more generating capacity. The TOU rates not only benefit the utilities, but also customers who can save money by planning electricity use during off-peak hours to take advantage of the cheaper rates (Ontario Hydro 1991). This rate system does not improve equity, as no cross-subsidisation occurs from the wealthy to the poor, but it does improve efficiency and thus should be considered as a viable option (Pickering 1994).

Increasing block rates are where prices increase at high levels of electricity usage, penalising excessive over-consumption. Furthermore, the initial block can be designed so that energy is affordable to low-income users (Levine et al 1992). In this way, cross-subsidisation from rich to poor households can occur. This type of rate may not be consistent with the cost of service-based rates, but it can be a powerful incentive for conservation (Nadel et al n.d.). The pitfalls with this form of tariff structure are that: firstly, it deliberately fails to allocate costs equitably; secondly, it is complex which may lead to confusion among end-users; and thirdly, international experience has shown that increasing block rates are open to political interference, resulting in an increase in the size, or a decrease in the rate, of the low rate block over time (Pickering 1994). Increasing block rates are not considered to be an effective option as they require regulation to ensure they are free of abuse from political manipulation.

The *flat rate tariff* has been singled out as the most effective option for South Africa. While it is considered to be less equitable than the increasing block tariff, it is simple to both implement and understand. Furthermore, it allows for redistribution of funds from the wealthy to the poor, while retaining a relative efficiency for reflecting service-based costs (Pickering 1994).

5.4.2 Thermal performance of housing

This seems to be one of the most important and applicable energy-efficiency strategies for South Africa. It has the potential to not only reduce the end-user demand for energy, but also to fulfil equity and development objectives by creating healthier, more habitable living environments and by freeing domestic financial resources for other needs, thus raising the general standards of living. Furthermore, the benefits accruing to the household from improvements in thermal efficiency of housing is not specific to any one fuel. For the effective implementation of such a strategy, it is essential that the target market is clearly defined and that the thermally efficient housing is affordable for that market or is secured for them. This is especially important in South Africa, where one is faced with a very poor low-income population and where downraiding in the housing market is consequently a real problem. Encapsulated in this is the need for flexible standards and guidelines for design.

It is much cheaper and simpler to install conservation measures while a home is being built than to retrofit these measures later. At the time of construction, conservation measures can be installed for only the incremental cost beyond standard building practices. New construction conservation opportunities are often referred to as 'lost-opportunity' resources, because if the conservation measures are not installed at the time of construction, then those opportunities may be forgone (Nadel 1991). The mass housing programme of the RDP promises massive construction activity in the low-income residential sector. Thus, South Africa is faced with an opportunity to implement energy efficient design techniques on a large scale.

Drawing on the international experience, a number of strategies which can promote the adoption of thermally efficient housing design nationally can be identified, including:

- information and awareness programmes;

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[2] Except as potential energy, for example, in the case of pump storage.

- codes and standards;
- training; and
- research and development.

5.4.2.1 *Information and awareness programmes*

One of the major constraints on the widespread application of thermal efficient housing design is that energy-decision makers - houseowners, architects, designers and planners - are unaware of both the technologies available and the savings that can be achieved through thermal efficiency improvements. A widespread dissemination of information is thus required to all the different stakeholders in order to promote the adoption of simple and cost-effective thermally efficient design. The provision of general energy conservation information through brochures and television advertisements can raise public awareness, but is unlikely to have an effect on actual end-user consumption behaviour unless it is part of a comprehensive effort including technical assistance, correct pricing signals, financing and efficiency regulations (Nadel et al n.d.). These programmes are most effective when they provide end-users with simple and specific steps to take along with estimates of how much energy and money can be saved and when the information is provided by a trusted and respected organisation whose motives are clear and unambiguous. Energy information centres can be set up to provide such information.

5.4.2.2 *Codes and standards*

International experience shows that substantial energy savings can be made through the application of mandatory building codes which set standards for the thermal efficiency of the building. These codes occur in two forms - prescriptive or performance-based codes. Experience demonstrates that:

- performance-based standards are preferable to prescriptive standards as they are flexible, stimulating rather than inhibiting technological innovation;
- the energy-saving effects of building codes are dependent on the level of training of architects, builders and inspectors, as well as the enforcement procedures; and
- codes must be revised regularly to encourage further technological improvements.

While performance-based building codes (National Building Regulations of 1987) do exist in South Africa, they may be waived by local authorities on the grounds of first-cost affordability. Areas in which these regulations are waived are called 'designated areas' and coincide with those areas where 'the concept of self help, core housing, roof schemes or shell housing apply'. Minimum Agreement Norms and Technical Advisory Guide (MANTAG) certifications apply in 'designated areas' and while they do include guidelines on thermal performance, they are not mandatory (Thorne 1995).

While first-cost sensitivity is an important issue in the low-income residential sector, it is essential that some standards for thermal efficiency of housing apply here. These should take into account the issue of affordability, while not compromising the significant savings that can be made from simple design techniques.

5.4.2.3 *Training programmes*

Capacity building of energy efficiency implementing agencies and staff is vitally important to the successful application of thermal efficiency improvements. Training of inspectors enforcing efficiency regulations, building designers and architects and those who provide technical assistance as part of energy conservation programmes is required (Nadel et al n.d.). This training can occur in a number of forms, ranging from seminars and workshops to post-graduate degree programmes at technikons and universities.

5.4.2.4 *Research and development*

Research into simple and affordable technologies is required. One of the barriers to the implementation of thermal efficient design is that of cost. It is thus essential that new cheap technologies, for example cheap insulation materials, are developed.

5.4.3 Appliance efficiency

South Africa's electrification drive is expected to increase sales in the consumer appliance market from an annual figure of R4 billion to a figure of R10 billion over the next five years (Creamer 1995).

Most of this growth in the appliance market is expected to occur in the newly electrified low-income market. It is essential that energy efficient appliances are promoted at the time of access to appliances, because most of the growth in appliance acquisition is expected to occur in the lower income groups whose appliance turnover frequency is low. Strategies to improve appliance efficiency aim to encourage both manufacturers to develop and produce more energy efficient appliances and to encourage end-users to buy these more efficient appliances. A number of different types of strategies have been implemented internationally. These include:

- appliance labelling programmes, which aim to increase end-user awareness of energy efficiency and to promote competition between manufacturers;
- end-user incentives, which aim to stimulate investments in energy efficient appliances;
- manufacturer incentives, which aim to stimulate technological innovation and advancement in energy efficient appliances; and
- minimum efficiency standards, which aim to increase the energy efficiency of appliances through regulation of manufacturer activity.

5.4.3.1 *End-user incentives*

These incentives should, in principle, relate to actions that are cost-effective from the point of view of the societal good, but would not be undertaken by end-users for a variety of reasons, such as poor information, lack of capital to overcome first costs and split incentives. Different consumer groups respond to different types of incentives. It is essential, therefore, that the programme incentive package is informed by the socio-economic circumstances and end-user preferences of the target group. The most commonly applied incentive schemes for low-income target groups are grants, leasing and give away and direct installation programmes.

Zero-interest or low-interest *loan programmes* can be provided for end-users to obtain the capital necessary to make energy efficiency improvements. Such loan programmes have been implemented with varying rates of success. The results of these programmes show that zero-interest loans result in higher participation rates than low-interest loans, and that end-users, especially low-income groups, generally prefer grants to loans.

Grants are direct or indirect payments to an individual or class of end-users, which give the recipients a financial incentive to purchase a particular good or service. Grants have targeted low-income end-users, with the aim of encouraging their participation in energy efficiency programmes, by aiding them in overcoming first-cost sensitivity. Grants have elicited high participation rates and have been successful in creating awareness, providing information to end-users and improving financial attractiveness of energy efficient measures. However, they are administratively expensive and costly (IEA 1989).

Leasing has been employed in programmes which target risk-averse and cash-poor residential populations to overcome the problem of end-users being unable or unwilling to make the high initial investment for buying the product. There are many examples of leasing with regards to compact fluorescent lightbulbs (CFLs). These programmes allow the end-user to spread the payment for their purchase of CFLs over their electric bills and have resulted in high participation rates where accompanied by information programmes. They result in substantial energy savings with little cost to the implementing organisation (Menanteau 1994).

Give-away programmes have resulted in the highest penetration rates of all the different incentive options employed (Mills 1991). These programmes are generally most successful when community-based organisations are involved in the marketing of the energy efficient technology. These give-away programmes are often linked to *direct installation programmes* where utilities or third party companies offer installation services to the end-users, thereby minimising the barriers to end-user participation of lack of time, money or expertise to install the measures themselves (Nadel et al n.d.). Direct installation programmes increase the penetration of energy efficient measures in to the market by offering a comprehensive service which can include installation, auditing and financing. Furthermore, they ensure that potential energy savings are maximised by allowing for professional installation and consultation.

5.4.3.2 Manufacturer incentives

Manufacturer incentives encourage the development and marketing of energy efficient equipment by overcoming market barriers such as negative regulatory prices and imperfect information. One such method which has been successful in transcending these market barriers is that of *technology procurement*. Technology procurement is the process of a purchaser attempting to accelerate development in a desired direction by pledging future purchases of something that did not exist at the time. Energy efficient government purchasing practices are often argued to be the most effective method of manipulating the market as government is often the single largest purchaser in a country. Alternatively, demand for energy efficient products can be created by bringing together important customers and formalising and expressing their requirements (Nilsson 1993).

5.4.3.3 Minimum efficiency standards for appliances

Minimum efficiency standards for appliances result in more rapid and quantifiable energy efficiency improvements than the use of financial incentives. If based on reliable assessments of what is technically and economically reasonable for manufacturers to achieve at a cost beneficial to the end-user, they can successfully achieve defined performance improvements within predetermined time-scales, thus forcing product development to occur at a faster pace than would otherwise have occurred. There are, however, limits to what regulations can achieve. For example, minimum efficiency standards for appliances are cost-effective methods of gradually cleansing the market of inefficient and inferior products, but it is difficult to encourage end-users to replace their existing appliances with super-efficient ones until the old ones wear out (Sioshansi 1994). End-user rebates and other incentives can accelerate the turnover rate of old appliances and increase the market penetration of newer, more efficient ones.

The following elements are those which have been identified as essential to the successful adoption appliance efficiency standards:

- The standard must be defined and measured in terms of an appropriate measure of performance. This requires the development of test procedures and adequate testing facilities. Internationally accepted test procedures are available from the International Standards Organisation.
- The equipment standard must be designed to require an appropriate level of efficiency. The proper level of efficiency will take into account the technical feasibility and costs and benefits to consumers and society.
- Mandatory standards need to have an adequate enforcing system and this enforcement and implementation requires authority and expertise, whereas voluntary standards cannot be enforced by government and they need to be accompanied by programmes to encourage their adoption.
- Mandatory performance standards should be applied to only those products which are easily controlled. This implies large consumer durables, such as refrigerators and washing machines, rather than smaller appliances, such as fans.
- Product standards must be preceded by effective product test programmes. Product testing is necessary to determine efficiency levels in available products. Product testing should be standardised to ensure that the efficiency savings are clear and unambiguous. The testing should be carried out by organisations that are beyond reproach and do not have an interest in the outcome of the tests (Miller 1994). With results from standardised testing, minimum efficiency standards and economic incentive programmes can be implemented. Product testing can also be used to support an efficiency labelling programme.

5.4.3.4 Appliance labelling initiatives

Appliance labelling initiatives, in conjunction with appliance efficiency standards and appliance testing and certification programmes, can have a profound impact on the adoption of energy efficient products. The primary goals of appliance labelling initiatives are to increase awareness of energy consumption and the potential for end-use efficiency, and to provide unbiased information to aid the purchasing decision (IEA 1989). It is expected that through raising awareness among end-users, purchasing practices will shift toward more energy efficient products, thereby expanding the marketplace for these types of products and speeding up the commercialisation of new technologies (Casey-McCabe and Harris 1995).

Internationally, appliance labelling programmes have enjoyed varying degrees of success. Some of the important issues emerging from the literature are:

- the labelling programme must take into account who the most influential players are in terms of appliance purchasing and efficiency improvements, and must target them (for example, the success of the programme may not be from end-user choice, but rather from the manufacturer responding to the programme as a challenge creating more efficient products);
- information about and *promotion* of the labelling programme is vital to its success;
- in order to encourage technological advancement, the requirements for endorsement of the product must be based on the setting of efficiency targets for manufacturers rather than on a specified top percentile range for energy efficiency of existing models on the market;
- manufacturer participation rates are higher when the initiative is programme-funded;
- appliance efficiency testing should be *standardised*, either by agreement between the manufacturers or by establishing a national testing programme, which should include the testing of imported equipment so that the accuracy of the energy efficiency information is legitimate, thus allowing for easy comparison;
- product energy efficiency should be tested by an independent, unbiased source to ensure that energy efficiency data is an accurate representation of the product's attributes;
- the format of and information on the label is essential to the success of the labelling programme. Research is required to determine what end-users best respond to - graphical representations such as endorsement logos or scales of comparison. The content of the labels must be clear, visible and easy to understand. With regards to the information on 'comparison labels', it is necessary to understand what measures of comparison end-users will best respond to - energy units, monetary units or efficiency indices; and
- where compliance is voluntary, as in Brazil, close collaboration between the implementing agency and manufacturers (on setting priorities for the programme and negotiating standards) is essential to the programme success.

5.4.4 Choice of fuels

While the focus of this international review has been on DSM strategies relating to electricity and to a lesser degree gas, it is essential that in the South African context a far wider range of fuels (and associated non-electrical appliances) is considered. Despite the electrification drive in South Africa, it is unlikely that the urban poor will switch to electricity on connection. The reasons for this relate specifically to the entry barriers to using electricity such as the cost of appliances and the method of payment for electricity. It is essential, therefore, that DSM strategies are implemented within an IEP framework taking the range of end-uses and fuels into account and find the most appropriate strategies to improve energy efficiency for the different appliance-fuel combinations.

5.5. Conclusion

While there are some lessons to learn from the international experience, South Africa is a unique situation and this must be borne in mind when selecting and implementing energy efficiency strategies. Strategies relating to the thermal performance of housing stand out as the most appropriate to the urban poor of South Africa. These strategies display the potential to not only reduce household energy consumption, but also improve the living standards of the poor by increasing thermal comfort and releasing income for other needs. When applied to electricity, these strategies can reduce peak electrical demand, thus avoiding additional generation capacity. When applied to other fuels, the strategies can reduce the amount of indoor pollution associated with heating of space.

With regard to appliances, low-income households are likely to first use electricity for lighting only. Thus, energy efficiency strategies should focus on efficient lighting in the low-income sector. This is markedly different to higher income-groups, where more efficient refrigerators, washing machines and other consumer durables may be the best appliances to target. South Africa can look to the efficient lighting programmes of Mexico and India for guidance.

Finally, it is essential that DSM strategies in South Africa do not consider options just in terms of electrical savings, but include other savings from other forms of energy, as well as savings in terms of health and environmental costs. This includes the internalisation of externalities in energy prices, as well as incorporating the social and political considerations surrounding the provision of energy services into analysis.

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