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Mark Malloch Brown, Administrator, United Nations Development Programme

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ENERGY FOR SUSTAINABLE DEVELOPMENT

A POLICY AGENDA

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The United Nations Development Programme (UNDP) is the United Nation's global development network, advocating for change and connecting countries to knowledge, experience and resources to help people build a better life. UNDP is on the ground in 166 countries, working on solutions to global and national development challenges. As local capacity is developed, national counterparts draw on the people and partners of UNDP.

The International Institute for Industrial Environmental Economics (IIIEE) at Lund University, Sweden, exists to bring new knowledge, education and renewed creativity to the urgent global search for sustainable systems of production and consumption. Engaging with industry, government, academia and civil society, the Institute aims to influence the process of sustainable development, and demonstrate the value of preventative approaches which address social, cultural, economic and environmental issues.

The International Energy Initiative (IEI), headquartered in South Africa, exists to promote – initiate, strengthen and advance – the efficient production and use of energy for sustainable development. IEI is a Southern-conceived, Southern-led and Southern-located South-South-North partnership. It is a small, independent, international non-governmental public-purpose organization led by internationally recognized energy experts, and with regional offices, staff and programmes in Latin America and Asia.

ENERGY FOR SUSTAINABLE DEVELOPMENT

A POLICY AGENDA

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Foreword

Ten years ago in Rio de Janeiro, the international community agreed on the overarching goal of sustainable development and it adopted a plan on how to get there – Agenda 21. The importance of energy systems in supporting many dimensions of sustainable development was a theme that echoed throughout Agenda 21.

Subsequent global conferences, dealing with small island states, social issues, women, human settlements, and food security also acknowledged the critical linkages between energy systems and many specific development concerns. In the platforms of action from each of the major United Nations conferences in the five years after Rio, there were consistent and clear calls for improved energy efficiency, commercialisation of renewable energy, technology transfer, and legislative and price reform to create what has become known as an 'enabling environment'.

Five years after Rio, the Special Session of the General Assembly formally recognized the need more sustainable energy use patterns. For the first time, an intergovernmental process focusing on energy was created to prepare for the ninth session of the Commission on Sustainable Development, which took place in New York in April 2001.

For that meeting, UNDP – in collaboration with the UN Department of Economic and Social Affairs and the World Energy Council – prepared the *World Energy Assessment: Energy and the Challenge of Sustainability*, a comprehensive analysis of available energy resources and technological options to support sustainable development. The assessment concluded that we *do* have the resources and technological know-how to rise to the challenge of energy that supports sustainable development. Doing this will require major shifts in policy – it will not simply happen on its own.

More recently, the world agreed on a common global development agenda at the Millennium Summit in August 2000 reflected in the Millennium Development Goals (MDGs). These ambitious objectives, particularly the overarching goal of halving extreme poverty by 2015, simply will not be met if the world cannot make rapid progress in extending efficient and affordable energy services to the 2 billion people currently who rely on traditional forms of energy for heating and cooking and to the 2 billion who have no access to electricity. Indeed, all the MDGs will require vast increases in the quality and quantity of energy services in developing countries if they are to be achieved.

In the ten years since Rio, the world has gained a more thorough understanding of the problems associated with energy use and of the actions that need to be taken. As we approach the World Summit on Sustainable Development in Johannesburg energy, and its relation with poverty reduction and changing patterns of consumption and production around the world, has emerged as one of the hottest topics. A huge increase in the scale, pace, and effectiveness of policy initiatives and measures will be required to shift energy systems and services to support sustainable development and to achieve the MDGs.

Some countries *have* made enlightened energy policies a priority, and many of their experiences are reflected in these pages. This book is intended to share information about such experiences and to shed light on policy options that can support an equitable, safe, healthy and prosperous world using energy as an instrument for sustainable development.

MARK MALLOCH BROWN

Administrator
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Overview and A Policy Agenda

THOMAS B. JOHANSSON AND JOSÉ GOLDEMBERG

Modern forms of energy empower human beings in countless ways: by reducing drudgery, increasing productivity, transforming food, providing illumination, transporting water, fuelling transportation, powering industrial and agricultural processes, cooling or heating rooms, and facilitating electronic communications and computer operations, to name just some of them. Given that they can so dramatically increase human capabilities and opportunities, adequate energy services are integral to poverty alleviation and environmentally sound social and economic development.

For such development to be sustainable, in the well-accepted definition put forth 15 years ago by the World Commission on Environment and Development, it must not compromise the prospects of future generations. Conventional sources of and approaches to providing and using energy are not sustainable by this definition. They are linked to significant environmental, social, and health problems for people alive today and, in many cases, pose even greater threats to future generations.

While it is imperative to find ways to greatly expand energy services, especially to the two billion people who currently rely on traditional forms of energy as well as for generations to come, this expansion must be achieved in ways that are environmentally sound, as well as safe, affordable, convenient, reliable, and equitable.

This, in essence, is the challenge of energy-related policies for sustainable development.

It is an enormous challenge. Over the next 50 years, sustained economic growth will require energy services an order of magnitude larger than today, with most of the expansion in the parts of the developing world that are presently underserved. During this half century, protecting human health and the environment demands that energy systems generate much less pollution. Taking the climate change threat seriously would require that carbon dioxide emissions be reduced by perhaps two-thirds compared to current levels. Furthermore, humanitarian and moral concerns dictate that modern forms of energy be made available to the one third of the world's people who are struggling today to improve their lives without this advantage.

Yet accomplishing energy systems supporting sustainable development in this century is in fact possible, according to comprehensive research on the subject by leading energy and development experts (see Chapter 1). It can be achieved through improvements in the efficiency with which modern energy carriers are produced and used, coupled with a greater reliance on modern forms of renewable energy and cleaner utilisation of fossil fuels using technologies now available or in the development stage.

However, these approaches are not being implemented widely enough to meet the needs of billions of people living today, nor are they taking hold quickly enough to safeguard the prospects for future generations. Without significant changes in policies that guide energy developments, the window of opportunity that is now open may well close down, and prospects for future generations will be dimmed.

The purpose of this volume is to offer informed guidance on the next steps, on how to shape public policy so that it accelerates the growth of energy systems that support sustainable development. As the following chapters describe, energy systems are diverse, technologically and institutionally complex, and in a state of flux. They are embedded within many different economic, political, and social arrangements. Policy makers are struggling to understand how to intervene most effectively to widen access, stimulate technological innovation, attract private investment, and refocus regulation to advance the economic, social, and environmental objectives of sustainability. Regrettably, there are no simple blueprints that will work in all situations.

Many instructive lessons can be extracted from developments in the energy sector over the past 15 years. The following chapters examine specific features of energy systems and public policies that can make them supportive of sustainable development. Case studies throughout this volume provide examples of what has succeeded, what has failed, and why. Broad principles that policymakers can apply to their specific situations are presented at the end of this overview.

The Challenge of Energy for Sustainable Development

Chapter 1 synthesises information and analysis from the World Energy Assessment, a collaborative work to which more than 100 scientists and development experts contributed. The chapter reviews critical patterns of energy use and the inter-connections between energy and social, economic, and environmental issues. As it notes, 80 percent of total energy consumption worldwide comes from fossil fuels used in conventional ways. This poses serious threats to human health and environmental balance, and undermines prospects for sustainable development. Promising technological options coupled with existing resources could fulfil the growing demand for energy services in environmentally and socially acceptable ways, given a supportive policy environment.

Patterns of energy use vary dramatically, in ways that reflect and intensify social and economic inequities. In industrialised countries, for example, primary energy per capita use is on average six times larger than in developing countries. Extreme poverty, and often attendant poor health, is exacerbated by the highly inefficient use of biomass fuels and traditional energy technologies that are widespread in the developing world. Traditional, non-commercial biomass fuels account for 90 percent of energy use in many low-income developing countries.

However, whereas commercial energy use is growing at a fairly stable rate of about 1.7 percent in industrialised countries, it is expanding at a rate of 3.8 percent per year in developing countries. Unless the increased demand for energy services is met using cleaner, safer and more efficient energy technologies, associated environmental and health problems will worsen.

Fossil fuels and traditional uses of wood and other forms of biomass are major contributors to serious environmental and health problems, and energy supply security that undermine a sustainable future:

- Particulate matter and other pollution from energy use threaten human health at the household and local level. Burning solid fuels in poorly ventilated spaces is one of the most significant causes of morbidity and mortality for women and children in the developing world.
- On a larger scale, the effects of a host of energy-linked emissions – including suspended fine particles and precursors of acid deposition – contribute to air pollution and ecosystem degradation.
- Globally, emissions of anthropogenic greenhouse gases, mostly from the production and use of fossil fuels, are altering weather patterns. Recent regional changes in climate, particularly increases in temperature, have already affected hydrological systems and terrestrial and marine ecosystems in many parts of the world.

- Although energy supply security has been adequate for the past 20 years in industrialised countries, the potential for conflict, sabotage, disruption of trade, and reduction in strategic reserves is high. Some large-scale energy installations are potential targets of acts of terrorism.
- In many of the least developed countries, energy imports consume a large percentage of foreign exchange earnings, hampering economic development.

The viable technical options for increasing energy services while decreasing their harmful side-affects include:

- More efficient use of energy, especially at the point of end-use in buildings, electric appliances, vehicles, and production processes.
- Increased reliance on renewable energy sources.
- Accelerated development and deployment of new energy technologies, particularly next-generation fossil fuel technologies that release almost no harmful emissions into the atmosphere – but also nuclear technologies, if the problems associated with nuclear energy can be resolved.

Energy scenarios suggest that a combination of these approaches can satisfy the energy demands of the growing world population (expected to reach 10 billion people by mid-century) while also meeting sustainability concerns – and with lower capital investments than implied by current trends. Indeed, developing the energy technologies needed seem to present less of a challenge than mustering the political will and developing the human capacity to employ them effectively. This will require changes of policies related to energy for sustainable development that go far beyond the energy sector. In fact, none of these scenarios will come about without changes in the policy environment. The new policies will have to be designed and implemented in the broader context of overall global development.

The Broader Context

Energy developments will affect and be affected by major global transformations occurring at the beginning of this new millennium. For instance, though world population continues to grow rapidly, for the first time in history, the number of people being added each year is less than the year before, and more people are living in urban than rural settings. Other major trends that set the stage for sustainable energy policies include:

Increasing globalisation. Trade barriers are transformed and world trade is growing. The global economy is becoming more integrated through mergers, acquisitions, joint ventures, and the expansion of multinational companies. Multinational companies are playing an increasing role in fossil fuel production and distribution, gas and electric systems, and manufacturing of energy end-use technologies. As companies and markets become increasingly international, policy interventions will require coordinated action and harmonisation in order to be more effective.

Shifting responsibilities for governments. The fact that market forces extend beyond national borders has made it more difficult for governments to raise taxes and still stay competitive globally. Government activities are increasingly moving toward rulemaking and monitoring the application of rules to ensure that markets work efficiently and advance social benefits.

Restructuring and liberalisation of energy markets. All over the world, the allocation of materials and human and financial resources, as well as the selection of products and technologies, is increasingly done by private actors, and partially a function of market conditions. Many nations are corporatising or privatising formerly government-owned utilities and petroleum and natural gas companies, and introducing competition and new regulatory frameworks, in part to increase efficiency and attract private capital to the energy sector. Government oversight is essential to protect public benefits in a market-driven energy sector.

The emerging information technology revolution. The microelectronics revolution and its various ramifications are well known. The economic and structural transformations from the information age are likely to have far-reaching and difficult-to-predict structural consequences, including a more rapid decoupling of primary energy use from economic growth than we have witnessed to date. The Internet and related information technologies also offer tremendous potential in terms of transfer of technology, building capacity and raising awareness.

Greater public participation in decision-making. The freer flow of information and increasing globalisation have been accompanied by a wave of democratisation. Throughout the world large numbers of people without economic power are gaining political power. Local groups are becoming more involved in the decision-making processes and affecting public policy formulation. Women are becoming more active in the political process. The growing inequities among and within countries are increasing potential for social disruptions and conflicts.

All these trends are likely to provide a growing impetus to keep sustainable development high on the political agenda. They also form an important part of the context for implementation of energy for sustainable development.

Making Markets and the Public Sector Work Better

As the energy sector becomes more market-driven, public sector oversight is perhaps more important than ever. Chapter 2 identifies features of the energy system that call for continued and new forms of regulation in the supply and distribution of energy even as the sector becomes more market-driven.

Despite the efficacy of markets in allocating goods and services, and the trend for more competition in the energy sector, there are three key reasons for which energy systems that support sustainable development cannot be left to markets alone:

- The inseparability of social and economic progress from access to modern energy services may require carefully designed subsidies to widen access in developing countries.
- Significant negative environmental and social impacts (local and global) of energy use that are not reflected in energy prices are increasingly the focus of energy policy.
- Natural monopoly characteristics of some elements of the energy system, such as electric grids, exclude competition as a means to achieving economic efficiency.

The relative importance of these three rationales will vary by country and sector. Developing countries, for instance, have an urgent need to expand energy services for economic growth. Economies in transition need to introduce more competition and improve planning mechanisms to drive down the costs of energy services and attract investments. Industrialised countries have greater responsibilities in terms of reducing carbon dioxide emissions.

Moreover, well-functioning markets are lacking in many of the countries where modern energy technologies are needed most urgently. Investment in energy systems demands a certain level of investor confidence that depends on factors beyond the energy sector, and falls more under the heading of good governance. Some such factors are political stability, an impartial and independent legal system, transparency of government regulations and open access to information.

The most obvious means of promoting competitive energy markets is to allow for competition from domestic and foreign suppliers and to corporatise, restructure and then perhaps privatise publicly owned energy entities, allowing prices to adjust to reflect market conditions of supply and demand. Implementation of this policy is, however, not easy and can lead to considerable social disruption and even political unrest from price shocks, worsening of unequal income distribution, and increased unemployment. Nonetheless, governments are replacing natural monopoly and/or publicly created monopolies with competitive markets where this can be effectively achieved. In the last decade, changes to the electricity sector in some countries have been especially dramatic.

The important element in this process is not privatisation, *per se*, but the introduction of competition (through restructuring or the entry of new independent power producers) to drive costs down, and the application of sound business principles in terms of pricing, reliable accounting, and transparency. It is also important to ensure that public monopolies are not simply replaced by private oligopolies, which have many of the same drawbacks.

Where well-functioning markets do exist, policies should attempt to make sure that competitors are playing on a level field. Two measures are particularly critical in this regard: removing subsidies and accounting for social costs or externalities. Global subsidies to conventional energy amount to about US$150 billion per year, leading to a significant distortion of many markets. Although subsidies may have a role to play in providing the poorest of the poor access to modern energy, few of the subsidies now in place serve this purpose. There are some notable exceptions. South Africa, for example, has used cross-subsidies to double the proportion of its population that have access to electricity during the 1990s.

Accounting for externalities in the energy equation, and thereby reflecting some of the social costs of energy use, has become an increasingly important aspect of energy policy. Many new approaches to address externalities have emerged in recent years. Market-based approaches include:

- Emission taxes.
- Fiscal incentives such as investment grants, investment tax credits and guaranteed prices for supplies from certain technologies.
- Ethical persuasion complemented by full disclosure about the social costs of various energy options.
- Certificate and emissions markets.

Several emerging hybrid approaches combine the efficacy of more interventionist approaches with the economic efficiency and flexibility of market-based approaches. The best-known example of this hybrid approach is a market-oriented regulation called the ‘cap and tradable permit mechanism’, which sets a total emission limit, or cap, for whatever entity is being regulated – a sector, a country or the world. It mandates the environmental target to be achieved and functions like a tax in providing a uniform cost signal – the permit-trading price – to all participants. Some may contribute to the achievement of the aggregate target by direct action; others may do so by trading for permits to emit. This encourages cost minimisation and continuous incentive for technological innovations to reduce emissions.

This approach can be generalised beyond emissions to regulations that specify some other attribute, such as the type of technology or the form of energy that is used. Noteworthy innovations are the renewable portfolio standard (RPS) in electricity generation and the vehicle emission standard (VES) in the automobile sector. Some countries are experimenting with trading among distribution utilities for energy efficiency improvements.

Although it can be difficult, especially in the initial stages, to determine what the appropriate target should be, regulations that include a market component are of special interest for the development of a sustainable energy system because they:

- Mobilise producers to make the long-term research and development effort needed for fundamental technological innovation.
- Intervene at the nexus of new product development and mass commercialisation, thereby helping to reduce technology costs by increasing the scale of production.
- Reduce costs by allowing producers the flexibility to trade among themselves in achieving the aggregate, regulated outcome.
- Provide an incentive for producers to rethink their marketing strategies. If producers can convince consumers to pay a premium for the value they believe they receive from renewable electricity or low emission vehicles, the financial benefits to producers increase.
- Affect just one sector of the economy, which reduces negotiation challenges and thereby increases the chance of policy support.
- Provide key social cost signals to producers but have minimal effect on consumer prices, which increases the chance of political acceptability.

Finding ways to account for externalities in energy markets would support large-scale improvements in energy efficiency; the costs and benefits of energy efficiency improvements are not always fully represented by a financial analysis approach. For instance, for householders, there may be a value in delaying or avoiding irreversible and long-term investments in new technologies for incremental, though long-term savings. Other barriers also exist.

Even without the transition to market conditions, it is possible to improve the functioning of natural monopolies and state enterprises. Avenues for improvement include:

- Pricing that generates adequate revenue to cover operating and capital costs, including investment in system expansion where warranted. As a rule, permanent subsidies to conventional energy should be phased out, to limit price distortions and encourage energy efficiency.
- Operating incentives to foster efficient investment and operation and investment planning.
- Certain regulations, such as price-caps on energy prices, encourage monopolies to operate more efficiently and pursue some of the innovations normally associated with conventional competitive markets. Another market-oriented reform possibility is to require competitive bidding for the licenses to monopoly concessions.

Integrated resource planning and other planning mechanisms designed to better allocate investment and increase efficiency can be advantageous in almost all cases.

Inclusion of energy considerations in community land-use zoning and infrastructure planning can have a dramatic effect on total energy use and the resulting social costs. Following this approach, several Latin American cities now take advantage of innovative land-use mechanisms pioneered in Curitiba, Brazil, combining them with relatively low-cost and energy-efficient bus transport solutions.

Towards a Sustainable Electricity Policy

As Chapter 3 discusses, traditional electricity, based on central-station generation and a monopoly franchise, has been successful enough to make electricity services such as electric light, electric motive power, and electronics essential to modern industrial society. However, traditional electricity has failed to reach one-third of humanity (specific policy issues related to improving access in rural areas are discussed in the following section). Its key technologies – large dams, coal-fired and nuclear power generation, and long high-voltage transmission lines – all face increasingly severe financial and environmental problems. Sustainable development will require electricity services that are reliable, available, and affordable for all, on a sustainable basis. However, the unique physical properties of electricity – a phenomenon that must be used the moment it is generated – complicate this challenge.

Nevertheless, the prospects are encouraging. Within the past fifteen years the rise of electricity liberalisation, and the accompanying upsurge of technical innovation, have dramatically widened the range of available options. Old certainties have been overthrown, opening the way for imaginative new approaches to using and providing electricity services. The challenges – as illustrated by the recent California experience (see Box 3-2, page 92) – are daunting, but should not blind policymakers to the opportunities.

Throughout the first century of traditional electricity, most systems were owned and controlled by governments. With captive customers and taxpayers bearing the risks, erratic investment, inadequate accountability, and other difficulties began to accumulate. At the end of the 1980s, governments with a strong commitment to free markets broke up their state-owned integrated monopoly systems, sold the assets to private investors, and introduced competition. New regulatory frameworks were put in place. In one form or another, this process of liberalisation spread rapidly across the world. It is now in continuous ferment.

The form of competition most evident to date involves electricity trading, particularly wholesale, in a market that may involve a 'pool', bilateral contracts or other business relations, including financial hedges. The distinctive attributes of electricity make this type of market differ from familiar commodity markets; the longer-term implications are uncertain. One problem is that unregulated electricity markets might not provide sufficient capacity margins to guarantee the reliability of energy systems. Waiting for the inevitable corrections of the market is likely to result in costly disruptions and extreme cost swings as occurred in the deregulation of the electricity market in California. Because reliable electricity is a vital public good, public oversight is needed. It is all the more important to ensure *system* reliability given the growing reliance on electronic communications and the expense of system failure. However, the responsibilities and policies of regulators are still evolving.

Electricity liberalisation, by reallocating risk away from users to shareholders and bankers, has altered investment priorities. Traditional generation, in large-scale long-term investments such as major dams and large coal or nuclear power stations, becomes very risky in a market context. The advent of gas-turbine generation, fired by cheap and abundant natural gas, is beginning a trend toward more and smaller generators closer to users, changing electricity systems away from the traditional centralised configuration to a more decentralised one. Other smaller-scale generating technologies, including combined heat and power, fuel cells, and for renewables such as wind power, biomass power, and photovoltaics, will become increasingly important. New technologies and institutional arrangements will be needed. Improving the networking capabilities of existing power systems is proving to be a challenge, including the demand for very high reliability of supply.

Liberalised electricity focuses on the sale of electricity by the unit at a customer's meter, and on the unit price. What customers actually want, however, is not electricity but electric light, electric motive power and other electricity services. What matters is the cost and reliability of the service; and the best way to improve it is often to improve the end-use equipment, not the rest of the electricity system. Traditional electricity tried to capture this opportunity through 'demand-side management' and 'integrated resource planning'. In a liberalised context, a regulator cannot mandate demand-side management or integrated resource planning, although some variants remain possible. Thus, specific policies to foster energy efficiency improvements are warranted.

On the other hand, competing to sell anonymous units of electricity to final users is a precarious business with minuscule margins. To win loyal customers on a longer-term basis, companies may offer contracts for services. Given adequate financial incentives, such contracts could entail upgrading buildings and other end-use equipment to deliver better electricity services and other energy services at lower cost. Government policies to foster improved infrastructure for energy services, for social, economic, and environmental benefits, should include tax regimes, asset accountancy, and other measures not hitherto adequately recognised as aspects of energy policy. Such an approach might also address the urgent problem of providing electricity services to the poor, in industrialised and transitional countries, as well as developing ones.

Electricity market liberalisation and privatisation could potentially threaten widened access to electricity for the poor. Private companies often have little motivation to seek out the poor with their precarious incomes and limited capacity to pay the full cost of service. Explicit policies and regulatory instruments are needed to expand service and targeted subsidies will be needed in many instances. Electricity market liberalisation, however, coupled with technological innovation, provides new opportunities to accelerate access to electricity. Governments could invite service providers to bid competitively for the lowest possible subsidies. If the bidding were so structured, new entrants would be encouraged to adopt innovative systems, approaches and technologies, with lower costs to reach unserved areas.

As electricity systems around the world undergo progressive transformation, policy should facilitate adoption of innovative technologies and configurations to improve the energy service infrastructure, especially for the poor. Getting energy right is clearly a prerequisite for sustainable development. Moreover, because of the distinctive attributes of electricity, and the present upheaval in electricity policy, getting electricity right is a promising avenue in this direction.

Policies to Encourage Rural Energy and Development

Energy systems are linked to almost every aspect of rural development. This means that policies that improve rural energy systems will have a synergistic effect on an array of social problems. As discussed in Chapter 4, far-sighted energy policies can have a dramatic effect on health and living standards, create new income-generating opportunities, enhance the position of women, encourage smaller families and reduce environmental degradation. Without improved access to adequate energy services the prospects of households breaking out of a cycle of poverty and ill health are dim. The critical domestic needs are liquid or gaseous fuels (and appropriate end-use devices) for cooking, and electricity for lighting, appliances, communications, food processing, and income generation.

The choice of which energy sources and systems to encourage should be guided by the degree to which they support sustainable development, including:

- Accessibility to the entire rural population, particularly the rural poor.
- Compatibility with high-efficiency end-use devices.
- Decentralised systems that can be manufactured or repaired locally (to strengthen self-reliance and to empower people/communities).
- Utilisation of renewable, locally available resources.
- Systems that can simultaneously produce heat and power.

The challenge of making modern forms of energy available to the rural poor is formidable, but surmountable. The basic strategy is to encourage the use of fuels and technologies that are higher on the 'energy ladder'. This implies moving from simple biomass fuels (e.g., dung, crops residues, firewood) to the most convenient, efficient form of energy appropriate to the task at hand – usually liquid or gaseous fuels for cooking and heating, and electricity for most other uses. Higher quality energy sources should be complemented by the synergistic use of modern, more efficient end-use devices, such as cooking stoves, light bulbs, and motorised equipment for processing agricultural products.

Climbing the energy ladder does not necessarily mean that all the rungs used in the past should be climbed. What is advised – whenever possible – is 'leapfrogging' directly from simple biomass fuels to the most efficient end-use technologies and the least polluting energy forms (including new renewables) available.

However, even moving from wood burning to liquefied petroleum gas or biogas for cooking is advantageous not only from a standpoint of health and safety, but also in terms of greenhouse gas reduction, because of the fewer unburned hydrocarbons released and the much greater efficiency with which the fuel is used. Taking this step up the energy ladder is eminently doable. The amount of gaseous fuels needed for safe, clean and efficient cooking in the developing world corresponds to only about 1 percent of the global commercial energy consumption. Already, more than 90 percent of households in South America use liquefied petroleum gas for cooking and there are more than 5 million household biogas digesters in China.

In addition, when it is used efficiently, the energy needed to substantially raise the standards of living of the rural poor in warm climates is actually quite modest, on a household basis. Provision of just 100 watts/capita (less than 15 percent of average use in industrialised countries) for instance, could mean a dramatic improvement in the quality of life for those who are without modern fuels and electricity.

Tremendous effort and investments (US$30–40 billion annually in the 1980s and 1990s) have gone into rural electrification, yet progress in this area has barely kept pace with population growth, and the number of people without electricity has remained near two billion for decades. Where progress in getting energy to the poor has been made, it has usually resulted from political will and appropriate public policies, not from market forces. Providing subsidised electricity to the *favelas* of Sao Paulo (see Box 3-4, page 109), for instance, was a policy decision that had far-reaching benefits in terms of health and safety. The access to mass media it enabled is often credited for the rapid decline in the local birth rate. The ongoing electrification of South Africa is not commercially viable, but is regarded as a long-term social investment with an indirect future return on capital.

In many of the now-industrialised countries, grid extension (often requiring substantial subsidies) was the only viable option for electrification of rural areas. Rural cooperatives in some countries, such as Bangladesh, have been effective in both implementing and financing grid extensions. However, long distances and low demand make this centralised approach prohibitively expensive for many rural areas. Village-level mini-grids utilising the most appropriate resources available – wind turbines, for example, or small-scale hydropower or diesel generators – may provide a more cost-effective alternative, especially for compact, high-density settlements. Ideally, these systems can be managed and maintained by local cooperative organisations. Stand-alone photovoltaic systems are viable options for isolated homesteads.

Subsidies and cross-subsidies were significant in bringing electricity to rural areas of most industrialised countries, but governments of many developing countries cannot afford to do more than they are already doing in this area. As liberalisation of energy markets proceeds, cross-subsidies are less likely to be an option. Given the poor prospects for foreign direct investment in many of these markets, most rural energy development will have to be financed domestically. However, this challenge is surmountable, if attention is paid to financing mechanisms and building of institutional capacity at the individual, village, and government levels.

Although poor households will typically not be able to come up with capital costs to improve their energy situation, they usually *can* afford to make some payments commensurate with their current expenditures on wood, candles, kerosene, and other fuels low on the energy ladder. Even if they are using 'free' resources, there are opportunity costs associated with the labour they expend in collecting them. The real or opportunity costs of traditional practices indicate the amount the household is capable of spending for alternatives. This relatively small amount can be enough to realise substantial improvements in the quality of life, in some cases even cover the lease of a photovoltaic system for household electricity.

The operating costs of traditional devices (e.g., kerosene lamps) are often higher than the operating costs of modern devices (e.g., solar cells and electric fluorescent lights). The size of the initial investment in modern devices is an important barrier to overcome. Loans (not necessarily soft loans) and leasing arrangements can convert unmanageable high initial investments into affordable operating costs. Innovative financing can be crucial, and microfinance institutions represent a very interesting development in this regard. This emphasizes the need for appropriate institutional solutions. If subsidies are used for this purpose, they should be transparent and time-bound.

New energy enterprises may also have to be established if local capacity does not exist to tackle the challenges of marketing non-conventional energy sources and energy-efficient devices. Another option is to allow the lowest qualified bidder a monopoly on delivering energy services to households in a specific region, provided they accept an obligation to serve also the poorest households in that locale. Joint ventures may have to be established to set up small-scale or renewable energy systems compatible with high-efficiency devices accessible to the rural poor. It may also be necessary to establish and develop micro-utilities (particularly those run by women).

Providing access to high-quality forms of energy to most of the rural poor will require time. However, substantial improvements could be made in the near-term that could greatly improve the standards of life throughout rural areas of the developing world. Examples of this include improved cooking fuels and stoves, electric lights rather than oil or kerosene lamps and motive power to replace human or animal labour. At the same time, longer-term strategies should be in the works to disseminate substantially improved energy technologies with significantly fewer harmful health and environmental side effects. Viable medium-term technologies (that could be implemented on a large scale within 20 years) include, for instance, compact fluorescent bulbs, more efficient motors and appliances, small-scale electric generators using renewable resources such as wind, hydro-power and biomass, and efficient combined cycle turbines using natural gas. Over the long-term, say by mid-century, much more advanced, efficient, and cleaner technologies could be widely disseminated, for instance, super-efficient appliances, and fuel cells for motive and baseload power.

The Innovation Chain

Technological innovation is pivotal to the re-shaping of energy systems in ways that encourage sustainable development. In fact, with only currently available technologies there is no long-term energy system compatible with sustainable development. Technically optimal solutions will not result automatically in a business-as-usual environment, nor will they arise quickly enough to meet the pressing challenge of sustainable development. There is concern that current spending on energy innovation, from both private and public sources, may prove inadequate. Far-sighted policies to accelerate and steer the innovation process are needed.

In the real world, innovation does not necessarily occur in a linear and sequential mode, nor can it be described solely in technical terms. Technology involves economic, technical, and social elements, all of which are highly intertwined, and its development and application is a social process involving many actors. Practical needs – that is, demand – influence supply, namely the types of research that is conducted. This relationship between the 'pull' of demand and the 'push' of supply has particular relevance for the developing world, which needs energy systems matched to specific circumstances and users. Innovation policies need to be embedded in a broader socio-economic context, and to deal not only with *market failures* but also with *system imperfections*.

The systems view of technological innovation has affected the way governments view their role in the process. Many have changed their focus from top-down control of the process, through supporting specific kinds of research and development, to looking for ways to ensure that existing knowledge is put to practical use. This form of steering innovation may include stimulating learning, cooperation, and knowledge sharing in an innovative climate, raising awareness, and encouraging user-supplier links.

Despite the overlap in various phases of the innovation process, it can be useful to think about discrete phases of the process: research and development, demonstration, early deployment, and diffusion. Policy instruments can be designed to help promising technologies get past particular hurdles along the way.

Some instruments, as discussed in more detail in Chapter 5, that can be used to direct or stimulate the early stages of innovation include:

- Formulating research priorities.

- Direct public funding of specific RD&D activities.
- Technology forcing standards.
- Corporate technology development agreements.
- Initiating and stimulating networks of innovation.

The spending of IEA governments on energy research, development, and demonstration (RD&D) has declined since the early 1980. Reported public spending has been falling steadily, from about US$15 billion in 1980 to approximately US$7 billion in the year 2000. Japan and the USA together account for about 80 percent of the year 2000 expenditures. A major share of the money, 47 percent, was spent on nuclear energy. The share of RD&D funding spent on energy efficiency was about 18 percent, on renewables 8 percent, and on fossil fuels 6 percent. There is thus a large potential for reorientation into more promising areas in support of energy for sustainable development.

For essentially all technologies and production processes, a substantial amount of experience or learning results from their application. This phenomenon has been observed to reduce costs from 10 to 30 percent each time cumulative production doubles. Public financial support in combination with other measures can be key to success. In the wind industry in Denmark, for example, a combination of private initiative and public policies, including subsidies, physical planning, and wind turbine certification, has produced a thriving industry with a 50 percent share of the world market in the late 1990s.

However, even after costs come down substantially, new technologies may face a range of barriers to widespread application. Some of these, such as information and transaction costs, can be the targets of specific government initiatives. For example, mapping of natural resources, simplified procedures for obtaining necessary permits, and use of standardised contracts. Other potential barriers, such as clear regulation of access to the grid and pricing of electricity from renewable energy, are very important.

Over the past few decades, a portfolio of policy instruments has been devised to encourage the early deployment and widespread dissemination of new energy technologies, while still taking advantage of the power of markets to accelerate and focus technological progress. They include:

- Target setting e.g. on energy efficiency or the use of renewables.
- Renewable resource development concessions, similar to those used in the petroleum sector.
- Dynamic technology performance standards.
- Taxes and fees, e.g. to internalise external costs.

- Certificate markets for reaching targets for emissions limitations (e.g. sulphur dioxide or carbon dioxide) and/or penetration of renewables or energy efficiency.
- Favourable feed-in tariffs, e.g. for renewable electricity delivered to the grid.
- Subsidies with 'sunset' clauses.
- Venture capital provision.
- Technology procurement.

When compiling the portfolio of policy instruments to achieve innovations specific attention should be given to instruments removing imperfections in the (national) *systems* of innovation. In many countries system oriented instruments are heavily under-represented in the portfolio to date. More attention should be given to policies and instruments dealing with the building and organisation of sustainable energy innovation systems and the management of interfaces between potential partners in the innovation process. Finally, policy instruments are needed that can be applied to stimulate demand articulation and to facilitate the search for possible applications of new technologies, and to support vision and strategy-development. Some examples of such instruments are:

- Promotion of clustering and cooperation for innovation.
- Stimulating research cooperation between universities and industries.
- Raising public awareness e.g. by eco-labelling and community education.
- Enhancing education and training.
- Establishing appropriate legal and regulatory environments.

Most of the new demand for energy services will come from the developing world, which urgently needs multilateral and bilateral assistance in energy innovation. Instead of following the example of today's industrialised countries, developing countries have the opportunity to leapfrog directly to modern, cleaner, and more energy-efficient alternatives. Such assistance would yield considerable benefits also to industrialised countries, including access to new energy markets and external benefits such as reduced transboundary air pollution and reduced greenhouse gas emissions.

Particular attention needs to be given to innovation for circumstances found in developing countries. This is especially true for critical areas where progress is likely to be slow in industrialised countries, such as modernisation of biomass for cooking/heating and small scale combined heat and power generation. Technical operating environments are also often distinctly different from those found in industrialised countries. Strengthening the cooperation between industrialised and developing countries, as well as among developing countries, could be an important driver for this innovation.

Capacity Development

Capacity development is needed if the critical policy frameworks on functioning markets, the electricity sector, rural energy, and the innovation chain – are to be established. Capacity development can be understood as the processes of creating, mobilising, utilising, enhancing and converting skills, institutions, and contexts to achieve specific desired socio-economic outcomes, in this case, in keeping with sustainable development. Capacity building efforts in all of these areas are discrete elements of the capacity development process. The most critical constituencies for capacity development in this regard are:

- Government (the public sector, civil service, macro-planners, energy policy makers, regulators and other representative officials).
- Private productive sector (including the energy industry and producers of energy-using goods and services).
- Academia, specialists, NGOs, and media.

These capacities in many countries are weak or do not exist at all. The economic optimisation and social improvement that market reform is intended to encourage will not come about unless effective regulatory capacities exist to direct the functioning of the market. In order for state bodies and public institutions to carry out their responsibilities in these areas adequately, they will need specialised teams and tools, strategies, instruments, databases and measures. In order to mobilise financing for rural development, capacity in the credit sector – as well as partnerships with local organisations – must be strengthened. Regulations and oversight need to be applied not just to the energy sector, but also more generally, to ensure accountability, fairness and transparency in business, jurisprudence and institutional practices. Policies are needed to build capacity; likewise, legislative capacity is needed to shape wise policies.

Without the appropriate human capacity and institutional backup, many potential energy system improvements that could support sustainable development will be unrealised. Developing the appropriate skills, among a variety of stakeholders involved, in both the public and private sectors, and at various levels – from regional to local – is at least as much of a challenge as developing the kinds of energy technologies that will support sustainable development. *Thus, capacity development must be an explicit part of any successful strategy to use energy as an instrument of sustainable development.*

The public sector, both at national and local levels, is the key target and recipient of capacity development. Capacity development needs and activities must be addressed not only at the national and federal level, but must include local regulatory agencies, public sector institutions, and local stakeholders. Capacity development in central level agencies may serve to address the overall macro-framework issues needed in the energy, credit, technology, and related sectors, but will not translate into effective action with sustainable outcomes at the local level unless specific attention is devoted to local capacity needs.

As the process of energy sector reform, utility restructuring, corporatisation, and re-regulation proceeds, a priority must be to develop capacity in new regulatory agencies and for new regulators. These capacities in many countries are weak or do not exist and the objectives of market reform, in terms of economic optimisation and social improvement, cannot be reached unless effective regulatory capacities exist to direct the functioning of the market.

The complexity and magnitude of the rural energy challenge will require specialised capacity development. Centralised capacity development may address the overall framework issues needed in the energy, credit, technology and related sectors, however, will not translate into effective action with sustainable outcomes in rural areas unless specific attention is devoted to local capacity needs. The manufacture, dissemination, maintenance, and financing of new energy systems require specific skills that are not readily available in many countries. As appropriate energy systems become available to meet rural energy needs, people who can build, maintain, repair, and market such technologies must be identified and trained. While some technical, institutional, and entrepreneurial capacity does exist in rural areas, it should be enhanced and effectively directed to address specific circumstances. Effective local institutions, credit systems, and information-sharing mechanisms can be critically important in this regard.

Specific technical skills can also be developed through regional institutes. Effective centres of excellence and knowledge sharing exist throughout the developing world, but funding for their vital work is declining. The effectiveness of regional institutes is likely to be enhanced if they enjoy close links to energy user groups. Those links can encourage the skill sets needed to effectively innovate, adapt, and apply energy systems to the specific needs and resources of rural areas.

Equally important is identifying effective targets: individuals and organisations that can both benefit from improvements in energy systems and carry them forward. For instance, organised groups of women – who have so much to gain from access to new energy technologies – can be dynamic agents in their introduction and commercialisation. The skills they develop can have spin offs in other sectors as well.

Capacity development is a continuous process. This is one of many reasons that development assistance should move away from short-term projects to longer-term programmatic support. Experience has shown that project-based activities, eager to show results, often pay inadequate attention to strengthening institutional capacity and technical and managerial skills that are so critical to sustainability. Given scarce resources, priorities should be domestically defined and considered within national resource allocation processes. Means of verification and follow-up should form part of the design of capacity development processes. The role of civil society organisations can be critical in supporting this feedback loop. The various stakeholders both within the energy sector and linked to energy utilisation should be seen as the objects of capacity building as well as the means of further capacity development. International funding and support should focus more on the institutions and stakeholders that bring about energy systems change and not merely on specific projects. Project-based funding emphasises technology selection and does not support institutional capacity and local sustainability. The international community, especially multilateral development assistance agencies mandated to support sustainable development, poverty reduction, and economic growth objectives, must place greater emphasis and support on capacity development as the focus of development assistance and as an overall means of achieving these objectives. While domestically driven capacity-needs identification must be the overriding principle, the international community can be a critical support of these goals.

A Policy Agenda

The advantages and drawbacks of a variety of policy instruments, and the circumstances under which they are most appropriate, are described in greater detail in the following chapters. The following are some general principles for decision-makers and programme designers to use as a framework when formulating policies for their unique situations.

Develop capacity: All of the approaches below depend on human skills and knowledge, as well as institutional and government support. Thus, attention to capacity should be considered a crucial and cross-cutting element of all development cooperation and energy sector programmes. The most critical targets for capacity development in the energy sector are macro-planners, energy policy makers, and new regulatory agencies. The ongoing process of energy sector reform, utility restructuring, corporatisation, and re-regulation demands regulators who can keep up with the quickly changing conditions – and this applies equally to industrialised and developing countries. The objectives of market reform, in terms of economic optimisation and social improvement, cannot be reached unless effective regulatory capacities exist to direct the functioning of the market. Capacity development should be a priority in new policy frameworks, and funding for capacity improvements should be part of domestic energy planning and development cooperation. Special attention needs to be given to the multi-sectoral capacity needs of rural areas.

Improve energy efficiency, especially at the point of end-use: Enhancement of end-use equipment can generally provide energy services more economically than improvements in generation or distribution. In addition to reducing externalities associated with energy use, improvements in energy efficiency can stimulate new industries in energy-saving goods and services. Pricing energy right (and metering it) is important, but not sufficient to overcome the significant barriers to efficiency improvements. Barriers include transaction costs, high initial and perceived costs of new technologies, and lack of information, technical knowledge, and training. Energy service companies, who typically contract for a given level of energy services, can overcome some of these barriers because they have the incentive and expertise to find the least costly, most energy-efficient mix of options. Public sector procurement policies can be helpful for similar reasons. Specific policy instruments can target different players – from consumers and builders to car manufacturers, urban planners, and industrial designers and engineers. Some of the approaches that have been effective in various contexts include energy-efficiency standards and labelling, low-interest loans to cover investments in energy improvements, large-scale procurement that incorporates energy-efficiency requirements in the bidding process, educational campaigns, tradeable certificates for energy efficiency improvements, tax incentives, and voluntary agreements. For larger public entities or private enterprises, integrated resource planning can be used to identify the least-cost options of meeting the need for energy services, looking at both supply and demand.

Target rural areas: Policies aimed at expanding modern energy technologies to rural areas should be flexible enough to support a range of options, depending upon what is appropriate to the situation. For instance, they should not give an advantage to centralised supply where village or household systems may be more cost-effective. Policies and programmes should encourage user participation in the choice of technologies and should target women as users, operators, and entrepreneurs in rural energy systems. They should foster the development of local capacity, especially in the areas of operation, maintenance, and financial management. Local manufacture and marketing of energy technologies offers a possibility of income generation along with important skills development. Realistic financing arrangements – whether through donors, local financial institutions, or new enterprises – that convert unmanageable high initial investments into affordable operating costs should be considered an integral part of rural energy programmes. Governments should simultaneously pursue energy strategies that will make a difference over the short, medium, and long term.

Encourage energy innovations: In order to support sustainable development, policies need to promote innovation in cleaner and more affordable energy technologies that can be practically employed in a wide range of real world situations. Interventions should aim at helping the most promising energy innovations surmount bottlenecks wherever they occur in the innovation chain. Increasingly, however, this chain is viewed as a complex, interactive system requiring networks of innovation, knowledge sharing, and demand 'pull' as well as supply 'push'. This view of the process gives rise to additional policy instruments to overcome system imperfections. Significant assistance and technological cooperation are needed to accelerate the energy innovation chain in the developing world. Over the past two decades, countries have experimented with a growing number of policy instruments – from target setting and procurement policies to green labelling and fiscal incentives. Many of these use market forces to achieve economic efficiencies as they steer the innovation process in the direction of renewables, energy efficiency improvements and cleaner uses of fossil fuels.

Use (and guide) the power of markets: Throughout the world, markets are playing a larger role in energy investment decision-making and in the determination of energy prices. When they are functioning well, markets sustain the pressure on competing producers to find productivity gains, which creates a continuous force for technological change that improves the efficiency with which resources are converted into valued goods and services. However, market-based approaches are no panacea – especially in the energy sector, where significant market imperfections require attention and oversights. In many countries, markets barely function. Huge populations, of both city dwellers and rural families, are excluded from markets by extreme poverty. Policies to improve the functioning of markets for energy include:

- *Price energy correctly*: Prices should cover all costs and needed investments, and thus ensure adequate revenue for the company or agency providing the energy. Earned revenues should cover operating and capital costs, including investment in system expansion where warranted, although this may be difficult to achieve in many developing countries. Rates should also take account of differences between the marginal and the average costs of providing goods and services. However, while pricing reform can lead to economic efficiency, it is important not to pursue such reforms without regard to other sustainability objectives. Changes in tariff design can lead to substantial shifts in the revenue requirements from different customer groups, so these distributional effects may need to be offset with some form of compensation or softened by a lengthy transition period.

- *Restructure subsidies to support sustainable development*: For political reasons, subsidies and cross-subsidies, usually implicit rather than explicit, have typically been a feature of tariff structures. The current large subsidies to conventional energy (about US$150 billion a year) represent a substantial market distortion, discourage new entrants into the market, and undermine the pursuit of energy efficiency. Modest, time-limited subsidies – sometimes in the form of small amounts of electricity to satisfy households' needs – may be justified for social and environmental objectives. However, substantial subsidies are both unsustainable – due to a lack of ongoing financial means – and harmful to economic growth – due to resources not being used efficiently. Moreover, they often do not go to the people whom they are ostensibly designed to help. Generally, subsidies to cover capital improvements rather than operating costs are most effective. Subsidies may also be used to promote technological advances and organisational learning. However, they are unlikely to lead to sustainable markets unless they create conditions whereby they are no longer needed. They should be applied with attention to private sector conditions in the market.

- *Address externalities*: In the absence of intervention, markets fail to address the substantial negative side-effects of conventional energy use. External costs can be as large as or larger than the private costs. In some cases such as certain effects of climate change, it has been argued that the external costs may be 'infinite' for practical purposes. However, as more attention has focused on external social and environmental costs, a variety of instruments and approaches have been devised to improve the functioning of markets, either through restrictions or prices. A general term for the analysis behind such policies is social costs, which is defined as the combination of private financial costs (those capital and operating costs normally seen in the market) with uncompensated negative externality costs. One way to do this is through information, labelling and pricing policies to change consumer behaviour to favour 'greener' products. Governments may also take a more dominant role by, for example, specifying emission levels or efficiency standards. A number of emerging hybrid policies, such as renewable portfolio standards (RPSs) and certificate markets, so called 'cap and trade' policies, combine the efficacy of regulatory approaches with the flexibility and cost-effectiveness associated with market-oriented pricing policies.

- *Promote transparency*: Complete information is a pre-requisite of a well functioning market. However, in the energy sector, as elsewhere, complete information is difficult to obtain. For instance, there is no simple way to measure the social and environmental costs of energy externalities. Assessments of long-term energy costs on large purchases and investments can influence decision-makers. Green certificates and product labelling are instruments that can affect consumer purchasing decisions through provision of information.

- *Mobilise private investment*: Capital investment in plants, equipment, infrastructure, and new technologies is a prerequisite for energy development. Much of this investment will have to come from the private sector, either from domestic savings or foreign direct investment. However, mobilising private investments requires a well-functioning market-oriented economy in which investors have some confidence. Thus, in many countries, mobilising investments in energy may require a broad series of fundamental legal, institutional, and social reforms and developments. These are proving to be difficult to achieve and could take a long time. In the meantime, efforts to pool domestic savings and to convert high investment costs into more manageable running costs are needed.

- *Re-regulate liberalised electricity markets*: Competition can drive costs down and open up opportunities for new players where well-functioning markets exist. Liberalisation, however, on its own, will not protect or enhance public benefits. Moreover, oligopolies may replace monopolies, with limited benefits to consumers. Thus, regulation is even more critical in a liberalised energy sector. In the power sector, someone must have responsibility for ensuring *system* adequacy and reliability. A regulatory framework should be established before energy corporations are privatised.

Adopt a systems perspective in policies regarding energy for sustainable development: Energy supply or demand, being integral to most sectors of policy making in societies, must be an explicit part of the considerations of policy in these sectors. These policy areas include poverty alleviation strategies, rural development, urban development, financial and trade policies, import duties, general tax policy, construction rules and practices, design of transportation systems, community energy planning, agriculture, industry, regional development, and others. With such a comprehensive approach in concert with more specific policies for energy for sustainable development, the opportunities and likelihood for success will increase.

1 The Role of Energy in Sustainable Development: Basic Facts and Issues

THOMAS B. JOHANSSON AND JOSÉ GOLDEMBERG

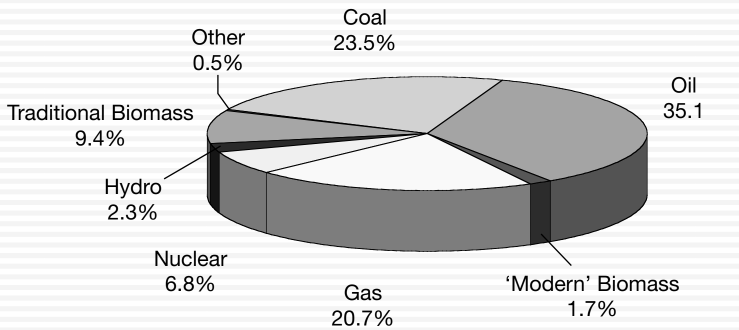
The concept of sustainable development refers to development that 'meets the needs of the present without compromising the ability of future generations to meet their own needs'.[1] This has social, economic, and environmental dimensions. In all three areas the way energy is used and produced plays an essential role. Current primary energy sources in the world are shown in Figure 1-1.

The energy system today is heavily dependent on the use of fossil fuels (coal, oil, and gas), which together account for 80 percent of global primary energy consumption. The large global energy system has the following characteristics:

- Total energy sales worldwide amount to some US$1 trillion per year (3 percent of the world's gross domestic product).
- Subsidies on fossil fuel sales are on the order of US$150 billion per year.
- Sales of 'new renewables' are on the order of US$20 billion per year.

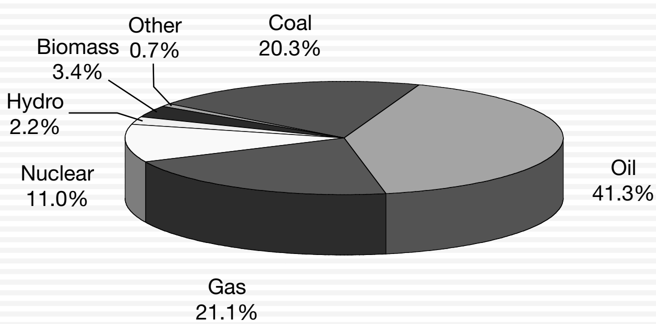
Figures 1-2 through 1-4 show the distribution of primary energy sources for industrialised, transition, and developing countries, and key facts about each of those systems.

FIGURE 1-1: PRIMARY ENERGY SOURCES IN THE WORLD, BY SOURCE, 1999



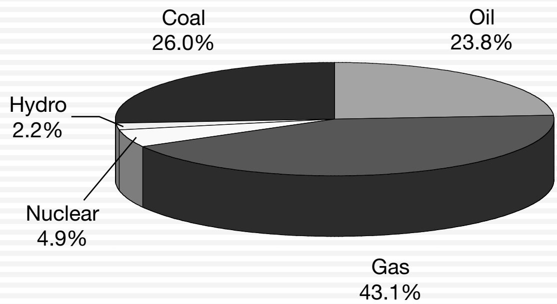
Population: 5.9 billion
Total energy use: 9,700 Mtoe (million tonnes of oil equivalent)
Per capita energy use: 1.6 toe per capita

FIGURE 1-2: PRIMARY ENERGY SOURCES IN INDUSTRIALISED COUNTRIES, BY SOURCE, 1999



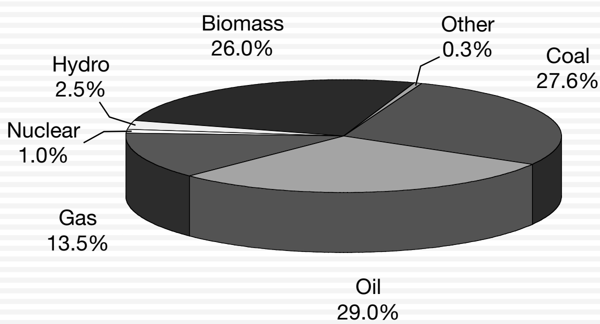
Population: 1.1 billion
Total energy use: 5,200 Mtoe (million tonnes of oil equivalent)
Per capita energy use: 4.7 toe per capita

FIGURE 1-3: PRIMARY ENERGY SOURCES IN TRANSITION-ECONOMY COUNTRIES, BY SOURCE, 1999



Population: 0.35 billion
Total energy use: 1,000 Mtoe (million tonnes of oil equivalent)
Per capita energy use: 2.9 toe per capita

FIGURE 1-4: PRIMARY ENERGY SOURCES IN DEVELOPING COUNTRIES, BY SOURCE, 1999



Population: 4.4 billion
Total energy use: 3,500 Mtoe (million tonnes of oil equivalent)
Per capita energy use: 0.78 toe per capita

Comparing across Figures 1-1 through 1-4 it is clear that countries differ significantly in the structure of their energy consumption. Fossil fuel consumption accounts for 83 percent of the energy consumed in industrialised countries and 93 percent in transition-economy countries, but only 70 percent in developing countries. In contrast, biomass represents only 3.4 percent of primary energy used in industrialised countries, is virtually non-existent in transition countries, and accounts for 26 percent of energy used in developing countries. Nuclear energy is also significant in industrialised countries (where it is the source of 11 percent of primary energy) and transition countries (5 percent), but it makes only a minor contribution in developing countries (1 percent).

The figures also highlight the extreme inequities in per capita energy use among groups of countries. Industrialised countries use 4.7 tons of oil equivalent (toe) per capita, in contrast to developing countries, which use only 0.78 toe per capita; the world average is 1.6 toe per capita. Although not shown in these figures, the rate of growth in energy use also varies across country groups. Between 1969 and 1999, worldwide average annual growth rate in primary energy use was 2 percent; in developing countries, it was twice that amount. This rapid increase was driven by population growth, and rising levels of economic avtivity. However, the increase has not resulted in more equitable access to energy services between industrialised and developing countries.

Energy and Sustainability: Key Issues

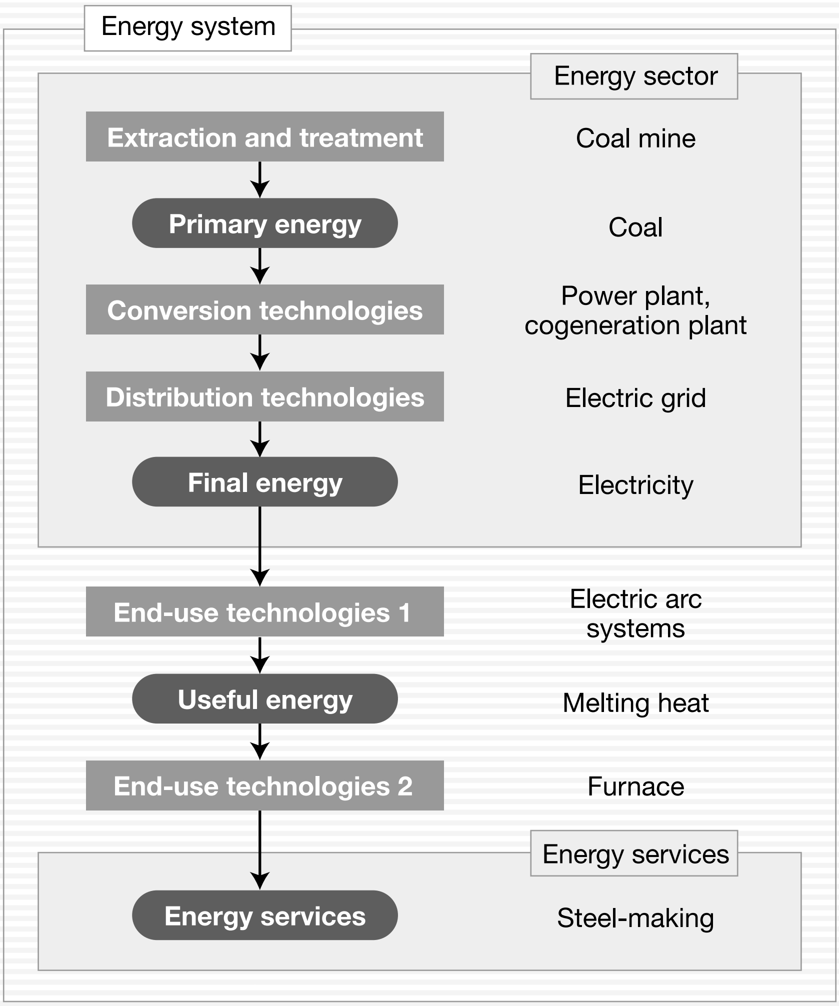
The pattern and profile of energy use prevailing today raises important questions about the linkages between energy and the economy, environmental protection, social issues, and security.

Economic Issues

During most of the twentieth century, primary energy supply has been cheap and abundant, however, due to limited emphasis on optimising the use of more energy efficient end-use technologies the energy system as a whole has evolved with limited regard for optimisation, because there has been little emphasis on optimising end-use technologies. The energy system is made up of the energy supply sector and energy end-use technologies; the object of the system is to provide energy services. If the end-use technologies are not efficient, the system cannot be efficient either. Figure 1-5 shows an example of how the energy system delivers energy services, going from coal extraction to the production of steel as an energy service.

One of the most important economic issue related to energy has to do with the relationship between energy prices and energy use. Energy prices influence consumer choices and behaviour. High energy prices can lead to high energy bills, which in turn has adverse consequences for business, employment, and social welfare. On the other hand high energy prices can also stimulate exploration and development of additional resources, create incentives for innovation and efficiency improvements,

FIGURE 1-5: AN EXAMPLE OF THE ENERGY CHAIN FROM EXTRACTION TO SERVICES



Source: United Nations Development Programme, United Nations Department of Economic and Social Affairs, World Energy Council. 2000. *World Energy Assessment: Energy and the Challenge of Sustainability*. J. Goldemberg (Chairman, Editorial Board). New York: UNDP.

and attract new investment. Energy system development cannot take place without investment in plants, equipment, and energy system infrastructure.

The oil crisis of the 1970s highlighted the importance of energy efficiency and ultimately contributed to a significant decoupling of energy consumption and gross domestic product. As a result, more products can be manufactured with less energy, and less energy is needed in general to create the energy services required. A major challenge will be to find ways of meeting the growing demand for energy services in developing countries to support desired economic growth without incurring the adverse consequences associated with current patterns of energy use. To accomplish this, significant investment will be needed to supply the two to four fold increase in global primary energy projected in the World Energy Assessment over this century.

Energy and Social Issues

Energy use is closely linked to a range of social issues, including poverty alleviation, population growth, urbanisation, and creating opportunities for women. In addition, poverty is the overriding social consideration for developing countries and poses one of the main threats to political stability in many countries.

Some 1.3 billion people in the developing world live on less than US$1 per day. Income alone, however, is an inadequate measure of the social conditions in which poor people live. The energy use patterns of the poor – especially their reliance on traditional fuels – tend to keep them impoverished. Increased income would not by itself address their needs and concerns, which include reducing physical labour for household chores, having access to safe potable water, and reducing the need to collect fuel.

Worldwide, 2 billion people are without access to electricity, and the same number use traditional fuels – fuelwood, agricultural residues, dung – for cooking and heating. Over 100 million women spend hours every day gathering and carrying fuelwood and water, and then spend additional hours cooking in poorly vented spaces. The stoves used often lead to significant health impacts, through the generation of pollutants that expose women and children to air pollution corresponding to smoking two packs of cigarettes a day. The hours women and children spend gathering fuel significantly reduce opportunities for education or more productive income-generating activities.

Although it is generally accepted that population growth tends to increase energy demand, it is less widely understood that the availability of adequate energy services can lower birth rates. Adequate energy services can shift the relative benefits and costs of fertility towards a lower number of desired births in a family. An acceleration of the demographic transition to low mortality and low fertility (as has occurred in industrialised countries) depends on crucial developmental tasks, including improving the local environment, educating women, and ameliorating the extreme poverty that may make child labour a necessity. All these tasks will require low-cost energy services. Providing energy services that can address the many social needs in developing countries will require major changes in the energy systems.

Energy and the Environment

The environmental degradation associated with the production and consumption of energy today, particularly fossil fuels, threatens human health and quality of life, and affects ecological balance and biodiversity. The Human Disruption Index (HDI) is a measure of the extent to which human-generated activities alter the environment. The HDI is defined as the ratio of human-generated flow of a given pollutant to the natural, or baseline, flow. In the case of sulphur, for example, human-generated emissions are 2.7 times the natural baseline flow; 85 percent of this disruption is a result of fossil fuel burning (Table 1-1).

Human environmental insults accelerated in the twentieth century, driven by a more than twenty-fold growth in the use of fossil fuels and a tripling in the use of traditional forms of energy, such as biomass. Current patterns of energy generation

TABLE 1-1: ENVIRONMENTAL AND HEALTH PROBLEMS CAUSED BY HUMAN ACTIVITIES (% CAUSED BY COMMERCIAL ENERGY SUPPLY)

Insult Due to Human Activities	Human Disruption Index	% Caused by Commercial Energy	
		Fossil Fuel Burning	Other
Lead emissions to atmosphere	18	41	
Oil added to oceans	10		44 (petroleum processing, harvesting, and transport)
Cadmium emissions to atmosphere	5.4	13	
Total sulphur emissions to atmosphere	2.7	85	
Methane flows to atmosphere	2.3		18 (fossil fuel harvesting and processing)
Nitrogen fixation (as NO_x and NH_4)	1.5	30	
Mercury emissions to atmosphere	1.4	20	
Nitrous oxide flows to atmosphere	0.5	12	
Particulate emissions to atmosphere	0.12	36	
Non-methane hydrocarbon emissions to atmosphere	0.12		35 (fossil fuel processing and burning)
Carbon dioxide flow to atmosphere	0.05	75	

Note: The Human Disruption Index is defined as the ratio of human-generated flow of a given pollutant to the natural, or baseline, flow.

Source: United Nations Development Programme, United Nations Department of Economic and Social Affairs, World Energy Council. 2000. *World Energy Assessment: Energy and the Challenge of Sustainability*. J. Goldemberg (Chairman, Editorial Board). New York: UNDP.

and use threaten human and ecosystem health at every level. A detailed analysis shows the following:

- At the household level, solid fuel use for cooking and heating has significant health impacts. About 2 million premature deaths occur every year from exposure to indoor air pollution caused by burning solid fuels in poorly ventilated spaces.
- The environmental impacts of a host of energy-linked emissions – including suspended fine particles and precursors of acid deposition – contribute to air pollution and ecosystem degradation.
- Emissions of anthropogenic greenhouse gases, mostly from the production and use of energy, are altering the atmosphere in ways that very likely influence the global climate. It is further estimated that a 60 percent reduction in emissions of these gases (mainly CO_2) must be achieved in the next fifty years in order to stabilise atmospheric concentrations of greenhouse gases.[2]

Preventing further environmental damage, or even reversing it, must be an important goal of energy policy. Finding ways to meet the inevitably growing demand for energy services without causing local, regional, or global environmental damage is a major challenge.

Energy Security

Attention to energy security – the availability of energy at all times in various forms, in sufficient quantities, and at affordable prices – is critical because of the uneven distribution both of the fossil fuel resources on which most countries currently rely and of capacity to develop other resources. The energy supply could become more vulnerable over the near term due to the growing global reliance on imported oil. For example, the oil dependence (net imports as a share of total demand) of industrialised countries is projected to grow from 56 percent in 1996 to 72 percent in 2010. In addition, although energy security has been adequate for the past twenty years, and has in fact improved, the potential for conflict, sabotage, disruption of trade, and reduction in strategic reserves cannot be dismissed. Present energy systems also provide targets for acts of terrorism. These potential threats point to the necessity of strengthening global as well as regional and national energy security.

Energy Resources

Contrary to some perceptions, the prospect of exhausting fossil fuel supplies is not an immediate concern. As Table 1-2 shows, coal reserves are abundant and should last for centuries. Oil and gas reserves are much smaller, but they are a ‘moving target’, that is, large deposits of unconventional resources exist that can be converted into standard energy carriers, effectively extending the projected life of oil and gas.

Technologies exist to convert the unconventional oil and coal occurancies to clean liquid and gaseous fuels at a cost of US$10/barrel or lower. As conventional oil supplies are depleted, such sources will become increasingly important.

Of course, consumption will increase as well, and the 'dynamic' Resource Base/ Production Ratio is more than double the 'static' Reserve/Production Ratio. Nevertheless, reserve-driven shortages of oil and gas should not be a serious concern in the next fifty years, although prices could climb significantly for other reasons.

TABLE 1-2: EXPECTED LIFE OF FOSSIL FUEL SUPPLIES, 1998 (YEARS)

Fossil Fuels	Static Reserve/ Production Ratio [a] *(years)*	Static Resource Base/Production Ratio [b] *(years)*	Dynamic Resource Base/Production Ratio [c] *(years)*
Oil	45	~200	95
Natural gas	69	~400	230
Coal	452	~1,500	1,000

a. Based on constant production at current rates and static reserves.
b. Includes both conventional (coal, oil, gas) and unconventional (e.g., oil shale, tar shale, tar sands, coalbed methane, and gas hydrates) reserves and resources.
c. Data refer to the energy use of a business-as-usual scenario – that is, production is dynamic and a function of demand.

Note: Resources are concentrations of naturally occurring solid, liquid, or gaseous material in or on the earth's crust in such form that economic extraction is potentially feasible; they are deposits that have known location, grade, quality, and quantity or that can be estimated from geologic evidence. Reserves are identified resources that are economically recoverable at the time of assessment.

Source: United Nations Development Programme, United Nations Department of Economic and Social Affairs, World Energy Council. 2000. *World Energy Assessment: Energy and the Challenge of Sustainability*. J. Goldemberg (Chairman, Editorial Board). New York: UNDP.

Renewable energy is a still more abundant resource. The base for renewable energy originates in the energy flow reaching the Earth from the Sun. This flow is of the order of ten thousand times larger than the current global energy use.

The Challenge of Sustainability

Although there seem to be no near-term physical limits to the world's energy supply, today's energy system is unsustainable because of equity issues as well as environmental, economic, and geopolitical concerns that have implications far into the future.

- Modern fuels and electricity are not universally accessible, an inequity that has moral, political, and practical dimensions in a world that is becoming increasingly interconnected.
- The current energy system is not sufficiently reliable or affordable to support widespread economic growth. The productivity of one third of the world's people is compromised by lack of access to commercial energy, and perhaps another third suffer economic hardship and insecurity due to unreliable energy supplies.
- Negative local, regional, and global environmental impacts of energy production and use threaten the health and well being of current and future generations.

Addressing these issues is the global challenge. Sustainable development is the global goal.

The Way Forward: Some Technical Options

Physical resources and technical opportunities are available – or could become available – to meet the challenge of sustainable development. However, without policy changes, price differentials and other factors may favour conventional fuels for many years. Options for using energy in ways that support sustainable development include:

- *More efficient use of energy*, especially at the point of end use in buildings, electric appliances, vehicles, and production processes.
- *Increased utilisation of renewable energy sources*, including biomass, solar, wind, geothermal, and hydropower, which have the potential to provide energy with zero or almost zero emissions of both air pollutants and greenhouse gases.
- *Accelerated development and deployment of new energy technologies*, particularly next-generation fossil fuel technologies that produce near-zero harmful emissions – but also nuclear technologies, if the problems associated with nuclear energy can be resolved.

Increased Energy Efficiency. Today the global energy efficiency of converting primary energy to useful energy is about one third. In other words, two thirds of primary energy is dissipated in the conversion processes, mostly as low-temperature heat.

Over the next twenty years the amount of primary energy required for a given level of energy services could be cost-effectively reduced by 25 to 35 percent in industrialised countries. And in most developing countries – which tend to have high economic growth and old capital and vehicle stocks – the cost-effective improvement potential ranges from 30 to more than 45 percent, relative to energy efficiencies achieved with existing capital stock.

The improvements of about 2 percent a year implied by these figures could be enhanced by structural changes in industrialised and transition economies, by shifts to less energy-intensive industrial production, and by saturation effects in the residential and transportation sectors. These combined effects, made up by efficiency improvements and structural changes, could lead to decreases in energy intensity of 2.5 percent per year.

Increased Utilisation of Renewables. Altogether, new renewable energy sources contributed 2 percent of the world's energy consumption in 1998, including 7 exajoules from modern biomass and 2 exajoules for all other renewables (geothermal, wind, solar and marine energy, and small-scale hydropower). Solar photovoltaics and grid-connected wind installed capacities are growing at a rate of 30 percent a year. (Table 1-3) Even so, it will likely be decades before these new renewables add up to a major fraction of total energy consumption, because they currently represent such a small percentage. Like most new technologies, they also tend to be more expensive when first introduced in the market; however, their cost is decreasing rapidly as their use increases. It has been estimated that a total investment on the order of US$30 billion over twenty years would bring the cost of photovoltaics down to a level competitive with conventional electricity in major markets.

Substantial price reductions in the past few decades have already made some renewables competitive with fossil fuels in certain applications in growing markets. Modern, distributed forms of biomass seem particularly promising for their potential to provide rural areas with clean forms of energy based on the use of biomass resources that have traditionally been used in inefficient, polluting ways. Biomass can be economically produced with minimal or even positive environmental impacts through perennial crops. Wind power in coastal and other windy regions is promising as well.

The installed capacity of 'new' renewable-based generating capacity has been increasing steadily. Figure 1-6 shows the installed capacity in 1993 and 1998, and the expected capacity in 2003 if the rate of growth that prevailed between 1993 and 1998 continues to 2003. This 7 percent annual growth rate would nearly double the installed capacity between 1993 and 2003. Electricity generating capacity from new renewables (including minihydro) amounted to approximately 100 gigawatt in 1998, which represents 3 percent of electricity generating capacity in the world (Figure 1-7).

New Energy Technologies. A technological revolution is under way in power technologies, in which old-fashioned systems are being replaced by a variety of advanced systems, including:

- Natural gas and gas turbine based technologies.
- Oxygen-blown coal gasification and integrated gasifier combined cycle technologies.
- Small engines for cogeneration (reciprocating engines and microturbines).

FIGURE 1-6: INSTALLED NEW RENEWABLE GENERATING CAPACITY, 1993–2003 (GWe)

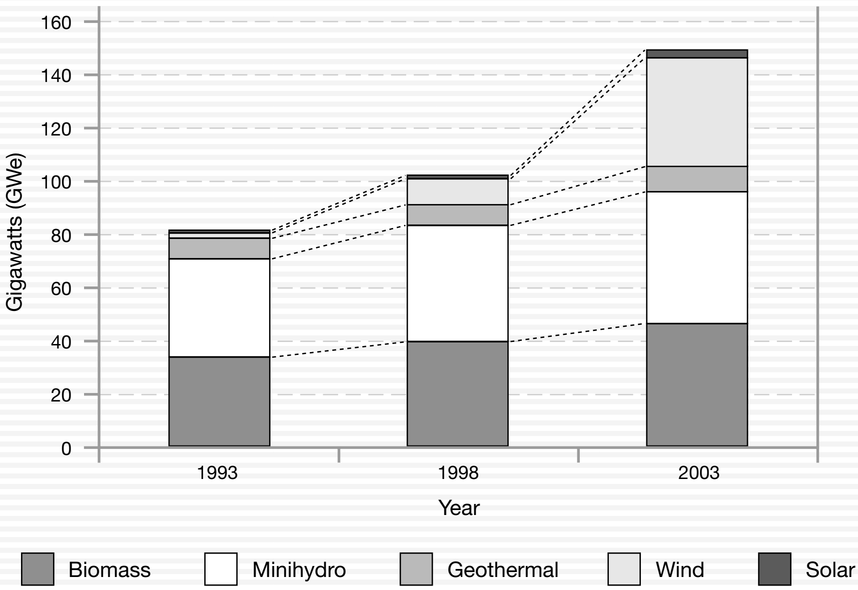
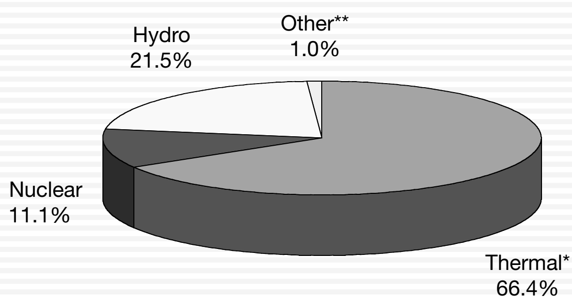


FIGURE 1-7: WORLD ELECTRICAL INSTALLED CAPACITY, 1999



Total World Installed Capacity: 3,180 GW

*Thermal capacity consists of coal, oil, and gas.
**Other capacity consists of geothermal, solar, wind, and wood and waste sources (excluding minihydro).

Source: Energy Information Administration (EIA), International Energy Database.

TABLE 1-3: STATUS OF RENEWABLE ENERGY TECHNOLOGIES, 1998

Technology	Energy Production (1998)	Increase in Installed Capacity in Past Five Years (%/year)	Current Cost
Modern Biomass Energy			
Electricity	160 TWh (e)	≈ 3	5 – 15 ¢/kWh
Heat [a]	>700 TWh (th)	≈ 3	1 – 5 ¢/kWh
Ethanol	420 PJ	≈ 3	8 – 25 $/GJ
Other 'New' Renewables			
Wind electricity	18 TWh (e)	≈ 30	5 – 13 ¢/kWh
Solar photovoltaic electricity	0.5 TWh (e)	≈ 30	25 – 125 ¢/kWh
Solar thermal electricity	1 TWh (e)	≈ 5	12 – 18 ¢/kWh
Low temperature solar heat	14 TWh (th)	≈ 8	3 – 20 ¢/kWh
Geothermal energy			
- Electricity	46 TWh (e)	≈ 4	2 – 10 ¢/kWh
- Heat	40 TWh (th)	≈ 6	0.5 – 5 ¢/kWh
Hydroelectricity			
Large	2600 TWh (e)	≈ 2	2 – 8 ¢/kWh
Small [b]	90 TWh (e)	≈ 3	4 – 10 ¢/kWh

a. Heat embodied in steam, often produced in combined heat and power systems.
b. Small hydro is usually defined as 10 MW or less, although the definition varies by country, sometimes extending to 30 MW.

Note: Modern biomass contributed 7 exajoules and other 'new' renewables contributed 2 exajoules in 1998.

Source: United Nations Development Programme, United Nations Department of Economic and Social Affairs, World Energy Council. 2000. *World Energy Assessment: Energy and the Challenge of Sustainability*. J. Goldemberg (Chairman, Editorial Board). New York: UNDP.

- Fuel cells for stationary power and cogeneration.
- Decarbonisation and carbon dioxide sequestration strategies.

Similarly, advanced fuels are beginning to replace traditional fuels for transportation. Examples include:

- Oxygenated fuels.
- Alcohol (ethanol and methanol).
- Syngas-derived fuels for compression-ignition engines.
- Polygeneration strategies for synthetic fuels production.
- Hydrogen as a new energy carrier, used in fuel cells.

All three options for addressing the challenges of sustainability – increasing the efficiency of energy, increasingly reliance on renewable sources of energy, and/or developing new technologies – have considerable potential. Realising the potential will require removing obstacles to wider diffusion, developing market signals that reflect environmental costs, and encourage technological innovation.

The strategies, and therefore the policies, needed to move toward a more sustainable future will for the most part need to be different in industrialised and developing countries, except for the segment of developing-country populations whose energy consumption resembles that of industrialised countries. The relatively unequal distribution of income in developing countries means that less than 20 percent of the population generally accounts for most conventional modern fuels (coal, oil, and gas) consumed, using similar consumption patterns as in the industrialised countries. The rest of the population has little or no access to modern fuels, relying heavily on biomass often using primitive and inefficient technologies. For the wealthiest segments of developing-country populations and the industrialised countries generally, the technical opportunities to move toward sustainability will be the same. Unfortunately, current policies and price differentials tend to favour conventional fuels.

For the vast majority of developing-country populations, however, who consume primarily non-commercial energy, the potential for designing and implementing policies that provide needed energy while meeting sustainability concerns is promising. This is particularly so in the case of biomass (e.g., dung, fuelwood, and agricultural residues).

The main challenge with respect to biomass utilisation is to modernise it by conversion into gaseous or liquid fuels and/or electricity. In some applications of traditional biomass, significant advances have been made by improving the efficiency of cooking stoves or switching to biogas or liquefied petroleum gas (LPG) as cooking fuel. The current level of cooking using traditional biomass could be accomplished with only 3 percent of the total current oil consumption by switching to LPG in the developing world, thereby solving the problem of cooking with inefficient and unhealthy fuels, at a cost of US$15 billion per year. Sugarcane converted into ethanol has proven to be a good replacement for gasoline. Modernisation of biomass is of limited interest in industrialised countries at present, and therefore need to be developed in ways that allow developing countries to 'leapfrog' the development path followed by today's industrialised countries.

It is possible to construct future energy scenarios in which a combination of approaches will provide the energy required by the world's population in a sustainable way. In fact, the World Energy Assessment did just that, analysing a variety of combinations of efficiency measures, choices of renewable sources of energy, and technological developments that could achieve the goals of providing more and better energy services, and do so in a sustainable manner. Indeed, such scenarios require lower capital investments than implied by current trends. **However, none of these scenarios will come about without changes in the policy environment.**

The rest of this volume analyses the kinds of policy changes needed to put energy in the service of sustainable development and discusses options in such key areas as the role of markets and governments in promoting sustainable development (Chapter 2), the special challenges in electricity generation and use (Chapter 3), energy technologies and policies that promote rural development (Chapter 4), the critical role of technical innovation (Chapter 5), and the need for capacity development at the local, national, and international level (Chapter 6).

For Further Reading

United Nations Development Programme, United Nations Department of Economic and Social Affairs, World Energy Council. 2000. *World Energy Assessment: Energy and the Challenge of Sustainability*. J. Goldemberg (Chairman, Editorial Board). New York: UNDP.

World Energy Council (WEC). 2000. *Energy for Tomorrow's World – Acting Now*. London: WEC.

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[1] World Commission on Environment and Development (the Brundtland Commission), *Our Common Future* (Oxford: Oxford University Press, 1987).

[2] IPCC, *Climate Change 2001: The Scientific Basis*, Contribution of Working Group I to the 3rd Assessment Report of the Intergovernmental Panel on Climate Change, Houghton, J.T., Y. Ding, D.J. Griggs, M. Noguer, P.j. van der Linden, X. Dai, K. Mascell, and C.A. Johnson (eds.) (Cambridge, U.K. and New York, NY, USA: Cambridge University Press, 2001).

2 Making Markets Work Better

MARK JACCARD AND YUSHI MAO

Energy plays a critical role in all societies, and governments have a long tradition of intervention and participation in the energy sector even in more market-oriented economies. But in recent decades, the need for and extent of government intervention has been challenged. A growing number of governments and international agencies now agree with liberalisation advocates that reducing public intervention in the energy sector can generate substantial economic benefits. At the same time, however, the environmental, social, and economic costs of poorly designed markets and ineffective government policy have become all the more apparent. The role of markets may indeed increase, but markets need to work better if the energy system is to become more sustainable. For that to occur, the public sector needs to work better, too.

This chapter presents an analytical framework for balancing the roles of the market and government and for improving the contribution of both to sustainability; this framework provides a background and context for the chapters that follow.

The chapter begins by discussing the traditional rationale for government intervention in the energy sector and shows how this rationale has evolved and what this evolution implies for energy policy objectives. Specific policy issues are then discussed, including identifying the potential benefits of liberalisation; reforming former monopoly sectors with the introduction of competition in specific circumstances; improving the operation of monopolies and state enterprises where these are retained; rethinking the role of subsidies and related policies in fostering energy system investment; and, finally, more directly and comprehensively confronting the damages and risks from the energy system so that markets and the public sector can work better to meet social and environmental needs.

The role and potential for markets and the public sector depend on the specific conditions in each country and region. The policies that work for wealthy countries with a long tradition of market economies may be inappropriate, or at least may require substantial modification, for less industrialised countries in which the majority of inhabitants lack access to commercial energy and have limited experience with modern market institutions.

Shifting Rationales for Government Intervention in Energy Markets

Throughout the past century, two rationales have dominated the argument for government intervention in the energy sector.[1] These are *natural monopoly* and *public good*.

Natural monopoly exists in sectors in which extreme economies of scale mean that a monopoly firm can provide service more cheaply than two or more competing firms. In the electricity sector, duplicate distribution grids owned by competing firms would entail higher production costs than a single grid owned by a monopoly. For most of the last century, natural monopoly conditions were assumed to exist throughout much of the energy sector; this included production, transmission, and distribution of electricity; transmission and distribution of natural gas; production and distribution of district heat; and pipeline transmission of refined petroleum products. Although not a pure natural monopoly, oil refining and distribution was also seen as an activity with sufficient economies of scale that oligopoly would develop in place of more aggressive competition.

In natural monopoly conditions, governments either create publicly owned monopolies or regulate privately owned monopolies. In oligopoly conditions, governments may regulate the private companies, create a publicly owned corporation that provides a window on private firms in the industry, or create a publicly owned monopoly. In all cases, the rationale for government intervention is to pursue economic efficiency while protecting customers from the potential market power of producers.

The second dominant rationale for government intervention is the *public good*. Some goods or services generate public benefits that cannot be fully captured in the prices charged by private producers, meaning that the market will underprovide the good or service. A classic example is a lighthouse; because non-paying users (free riders) cannot be excluded from benefiting, private investors have no incentive to build lighthouses and so governments provide them instead.

Although it is not a pure public good (because direct free riding by consumers can be prevented), commercial forms of energy nonetheless have public good attributes in that their provision is associated with more than just the benefits realised directly by consumers. Some examples:

- Electricity enables advanced communications, education, and training opportunities; more effective domestic lighting; dramatic time saving in domestic chores; more productive and reliable production processes; and many other social development benefits that markets tend to undervalue. Therefore, governments of industrialised countries, especially in the past, and developing countries, today, play an active role in pursuing widespread electricity access and use through state enterprises and public subsidies for energy production and for extension of distribution systems.

- Governments in developing countries attribute significant social benefits (improved indoor air quality, slowing of deforestation) from replacing the household use of biomass in inefficient, traditional stoves with cleaner and more efficient use of commercial fuels like propane and butane. To this end, governments may subsidise these fuels and acquisition of the stoves that use them.

- Private producers cannot capture the price stability and national independence a country obtains from stockpiling oil in preparation for unforeseen supply crises, so governments often accept this responsibility and expense.

These and similar public good arguments have been used historically to justify substantial government intervention in the energy sector in the form of public ownership, subsidies, and regulation. However, the public good rationale is more nebulous than natural monopoly, because it is relatively easy for politicians to detect public good conditions in any situation in which markets perform poorly (in hindsight) or seem incapable of developing fully (e.g., the unavailability of commercial fuels and electricity in developing countries).

Because the public good rationale is somewhat subjective, societies vary significantly in the extent to which they rely on it to justify energy market intervention. Some governments dominate their domestic energy market with state enterprises, controlled prices, subsidies, and regulations, while others are relatively non-interventionist. Not surprisingly, the industrialised countries, with their long history of commercial activity, generally allow a greater role for markets in the energy sector, while the governments of centrally planned and developing countries tend to dominate their domestic energy industries.

In the last two decades, technological change, shifting ideological preferences, and disappointments with past market interventions have reduced the influence of both the public good and the natural monopoly rationales.

- Technological change has undermined the rationale for natural monopoly especially in electricity generation; smaller, competing generators are now seen as cost-effective and less risky alternatives to large, monopoly-owned facilities.

- The collapse of most centrally planned economies coincided with the emerging market enthusiasm of right-of-centre governments, especially in the United Kingdom and the United States, in the 1980s and early 1990s. These countries ushered in a wave of liberalising reforms that expanded the market's role in many sectors, including energy. Thus governments deregulated natural gas commodity prices, reduced their intervention in the markets for refined petroleum products and oil and gas exploration, cut back on coal subsidies, and began to introduce competitive reforms in electricity generation. This has occurred especially in industrialised countries, but the liberalising movement has spread to transition and developing countries as well.[a]

- Governments in developing countries have been frustrated in their efforts to accelerate rural and low-income access to electricity and other commercial energy forms through a conventional strategy of central planning, dominant state ownership, public and aid-agency investment in energy production and delivery infrastructure, and energy commodity subsidies. This strategy is associated with inefficient state-owned energy companies whose revenues are artificially low because of politically determined prices, large commodity subsidies, unpaid bills, and corruption. Insufficient revenue from the energy sector makes it impossible to finance system expansion internally, and it discourages domestic and foreign private investors.

In summary, the public, politicians, and international agencies have become more aware of the economic efficiency costs of state enterprise, large subsidies, political interference, and excessive regulation of the energy market, whether the justification is natural monopoly, public good, or something else. The implications of this trend are discussed in this chapter in terms of policies needed both to make markets work better and to improve the effectiveness of monopolies, state enterprises, and other forms of government intervention where these are retained.

While the two traditional rationales for government intervention have declined, another has grown in importance. Societies are increasingly aware of the negative human and environmental impacts and risks associated with energy production and use, including:

- Indoor air pollution, especially for the two billion people in developing countries who still rely on biomass for cooking.

- Local and regional air pollution affecting all major cities, especially the metropolises of developing countries.

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[a] Transition economies are countries – within, or under the influence of, the former Soviet Union – whose economies were centrally planned and dominated by state ownership but which are now undergoing transition toward a private-ownership, market-oriented system.

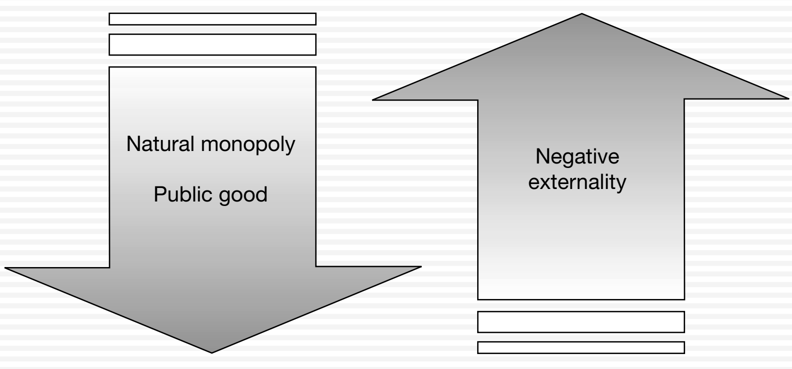
- Climate change risks threatening the entire globe, with some developing countries being especially vulnerable.
- Local threats to ecosystems and social groups from oil spills and petroleum exploration and development.
- Human and natural habitat disruption and loss from hydropower development.
- Widespread human and environmental risks from nuclear accidents.

Economists refer to these current and potential impacts as negative externalities: uncompensated damages or risks that are not accounted for in the price of a good or service. Because unguided markets will produce more of the externality-causing good or service than is socially desirable, governments may intervene in markets, or supplant them, in order to internalise externality costs. Discussed later in the chapter are a range of available options for improving the functioning of markets and the activities of governments when dealing with negative externalities.

Figure 2-1 summarises these shifting trends. Natural monopoly and public good rationales are in decline, although still substantial in many cases, while negative externality is increasing in importance.

Figure 2-1 does not show the considerable differences in the relative importance of these rationales among countries. With their established market traditions, industrialised countries are more willing to experiment with market replacement of natural monopoly, even where the efforts may produce unpleasant surprises (such as the recent electricity crisis in California). Developing countries can less afford to take such risks. Industrialised countries also see less need for government intervention in specific markets as a strategy for pursuing public good, in part because some public

FIGURE 2-1: SHIFTING RATIONALES FOR GOVERNMENT INTERVENTION IN ENERGY MARKETS



good objectives, like universal access to electricity, have largely been achieved. Developing countries, in contrast, still need to ensure that the poorest members of society are not left behind by liberalising reforms. This attitude is consistent with the public good philosophy that industrialised countries had during the last century when they were providing universal access to modern energy services. Finally, although both industrialised and developing countries are increasingly concerned about the negative externalities of certain energy forms and technologies, developing countries must consider the immediate quality-of-life improvements that their citizens so desperately need when making trade-offs between the current benefits of increased energy use and possible future environmental and social costs. This distinction between industrialised and developing countries is a recurring element in the policies presented and analysed throughout this chapter.

A Model for Characterising Government Intervention in Energy Markets

There are different ways to characterise the relative role of markets and government in the economy. Figure 2-2 portrays government's role in terms of the extent and form of its intervention in the economy. A highly interventionist approach (right side of the figure) is characterised by state enterprises and agencies, central planning, politically controlled prices, price subsidies, and command-and-control regulation. A non-interventionist, market-oriented approach (left side of the figure) is characterised by private enterprise (monopoly only in the case of pure natural monopoly), prices that

FIGURE 2-2: EXTENT AND FORM OF GOVERNMENT INTERVENTION IN ENERGY MARKETS

Minimal intervention – Emphasis on markets and market instruments ← ←	← →	**Substantial intervention – Emphasis on public ownership and central planning** → →
• Private ownership • Monopolies replaced by competition wherever possible • Prices determined by competitive markets • Externality taxes • No public good subsidies	• Minimal public ownership • Market-oriented regulation • Limited public good subsidies	• Publicly-owned monopolies • Central planning of investment • Command-and-control regulation • Controlled prices that diverge significantly from cost • Extensive public good subsidies

are predominantly market-determined, and a focus on price adjustments (taxes and tax credits) as the key means of addressing externalities.

For any market or sub-sector of a market, or any specific public concern, there are many options for where a society might situate itself along this continuum. No matter where it is situated, however, there are opportunities to improve how markets and government perform at any particular location. Thus some of the discussion in the following sections focuses on policies for moving along the continuum. These might be liberalising policies that shift towards a less interventionist approach or replace monopoly with competition. But some of the discussion is focused on how to improve the operation of markets and government at specific points on the continuum. These might, for example, be policies to improve upon the regulation, management, and pricing practices of monopolies and/or state enterprises. Some examples are provided here of how such policies have been applied in particular circumstances, which should help both industrialised and developing countries assess the appropriateness of a given policy for their unique circumstances and objectives.

Pursuing the Efficiency and Economic Growth Benefits of Competitive Markets

In much of the world, markets are playing an increasing role in energy investment decision making and in the determination of energy prices. This growing popularity of liberalising energy markets is attributable in part to the success of market-oriented economies in achieving economic efficiency – maximising the productivity of inputs – and thus dramatic economic growth. How does this occur?

Markets pressure competing producers to reduce costly inputs to production, that is, to find productivity gains. This creates a continuous force for technological change that improves the efficiency with which resources are converted into valued goods and services. In a planned economy, or a monopoly sector of a market economy, this same pressure is lacking. Also, because investments in any economy are made with imperfect information about the future, misinvestments – sometimes colossal – are to be expected. In a market economy, there is a greater ability for consumers to switch their allegiance from suppliers who have made less favourable investments to competitors who, through fortune or talent, can charge a lower price while recovering all costs. This forces the unfortunate suppliers to lower the price of their product in order to compete, and the consequent losses are borne by the suppliers' shareholders instead of by consumers or taxpayers. Bad investments may, in the extreme, lead to premature retirement of plant and equipment, accelerating society's reallocation of resources to more productive ventures.

In an economy dominated by monopoly, state-owned enterprises – or in a monopoly sector of a market-oriented economy – consumers lack this choice. All members of society bear the cost of poor investments and there is no pressure on monopoly producers to abandon such investments until the physical plant and equipment have reached the end of their operating lives. Government officials or the managers of monopolies determine prices, often in response to political considerations and the relative lobbying strength of interest groups such as farmers, households, and industrialists. These prices are usually set at or below the average production cost from all plants, which prevents consumers from distinguishing between good and bad investments. There is little incentive to improve the operating efficiency of existing facilities or perhaps even to ensure bill payment from customers.

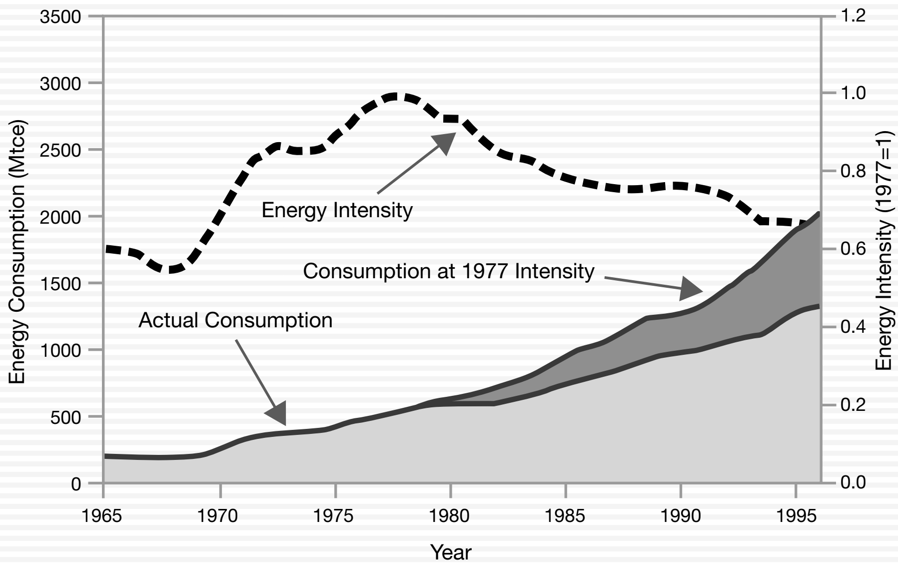
In the aggregate, these characteristics of uncompetitive markets can represent an enormous cost to society. In industrialised countries, for example, monopoly misinvestments in the electricity sector along with barriers to interregional trade have resulted in substantial economic costs. In developing and transition countries, such costs are exacerbated by poor operating performance (causing economic losses from power outages), high operating costs, unpaid bills, subsidised prices, and corruption. These inefficiencies drain financial resources that could otherwise be devoted to social needs such as health care, education, and direct assistance to low-income groups. To take an extreme example, power outages in Bangladesh are estimated to cost US$1 billion per year and reduce GDP by 0.5 percent; and electricity subsidies – which only assist the 16 percent of households with electricity service – amount to US$100 million per year, which is more than the government's health expenditures.[2]

Recent policy changes provide aggregate evidence that supports (but does not prove) the argument that energy productivity will improve as economies shift from central planning to a greater role for markets. Figure 2-3 shows how energy productivity (energy consumption per unit of GDP, measured by purchasing power parity) in China has improved dramatically since about 1980, when the government began to increase the role of markets. If energy productivity (as measured by energy intensity) had remained frozen at its 1977 level (it had been declining up to that time), energy consumption would have been 50 percent higher by 1997 for the same level of GDP than it actually was. Of course, one must be careful when inferring a causal link between markets and energy intensity; structural changes contributed, perhaps significantly, to China's energy productivity improvement (although structural changes may also have resulted from the increasing role for markets, starting first with reforms in agriculture).

The relationship suggested in Figure 2-3 is consistent with evidence from other jurisdictions. For example, energy markets in the United States over the last century, which have been generally more competitive than in most countries, have realised substantial reductions in the cost of energy supply. While U.S. consumers spent about 3 percent of their incomes on energy in 1900, their total expenditure for energy had fallen below 3 percent of income by 1990, in spite of the dramatic increase in energy consumption and energy-based comforts over that time period (e.g., appliances, central heating and cooling, transport, electronic equipment).[3]

An important consideration in developing countries is that an expanded scope for energy markets is associated with greater access to commercial fuels – electricity,

FIGURE 2-3: CHINA´S ENERGY INTENSITY TRENDS



Average annual energy intensity decline since 1977: 2.3 percent

Notes: Energy intensity is the ratio of energy demand to GDP. GDP is measured on the basis of purchasing power parity (PPP). The data exclude Hong Kong.

Sources: Energy consumption data from J. Sinton (ed.), *China Energy Databook* (Berkeley, CA: Ernest Orlando Lawrence Berkeley National Laboratory, 1996), Table IV-1. GDP (PPP) data from A. Maddison, *Chinese Economic Performance in the Long Run* (Paris: Organisation for Economic Cooperation and Development, Development Centre, 1998), Table C.5.

diesel, and liquefied petroleum gas (LPG) – for the poorer members of society, and this can have significant social and economic development benefits. Biofuels currently account for one fourth of energy use in developing countries, most of this by poor households; indeed, biofuels are the primary energy source for two billion people. From a total cost perspective, biofuels are expensive. The quality of energy is low, a great deal of time is required for gathering fuel, and combustion for cooking and heating has significant health impacts, mostly from poor indoor air quality. The effective cost of energy for poor households, therefore, is in the range of 10–20 percent of income, while higher-income households in the same country, using commercial fuels, will typically spend only 2–3 percent of their income on energy.[4]

Thus, although the reasons may differ and the specific solutions may differ, governments in industrialised, transition, and developing countries acknowledge the potential benefits of bringing a greater role for market competition to the energy sector. However, this greater role for markets can occur in two ways: it may involve shifts to the left along the continuum of Figure 2-2, or it may involve better integrating some of the benefits of markets at points along the continuum. The next section looks at movement along the continuum, and subsequent sections focus on improving the performance of monopolies, markets, and the public sector at specific points on the continuum.

Liberalising Energy Markets

Because of the historical importance of the natural monopoly and public good rationales, state enterprises and private monopolies dominate significant components of the energy sector in most countries. Liberalisation strategies involve policies such as corporatisation of state energy agencies, privatisation of energy companies, deregulation of energy prices, removal or reduction of energy subsidies, and other institutional and legal reforms to encourage direct investment by foreign and domestic companies.

Implementing a liberalisation strategy is not easy, however. The natural monopoly and public good arguments are still important in the eyes of many, and individual interest groups are dependent on various subsidies and institutional arrangements. Thus the transition from public to private ownership, and from controlled prices to market prices, can lead to social disruption in the form of consumer price shocks, increased inequality in income distribution, increased unemployment, and even political unrest.[5] Such reactions have happened in all types of countries, but have been especially pronounced in developing countries.

In the last decade, the liberalisation movement has focused especially on the electricity sector, where the assumption of natural monopoly in electricity generation has been undermined by technological and cost changes favouring smaller generating units. Starting with reforms in Norway and England, many jurisdictions have replaced monopoly with competition in the generation sector.[6] In most jurisdictions, this reform has unfolded relatively smoothly; ownership of generation has been separated from transmission and distribution, with the generation units divided among several competing firms and the price of electricity deregulated. Publicly owned facilities have been privatised, although not in all cases, and the market has been opened for competition from new firms.

This liberalising trend has not been limited to industrialised countries in Western Europe, North America, and Australia. Jurisdictions in developing and transition countries in Asia, South America, and Eastern Europe have experimented with competitive electricity reforms.[7]

California’s recent misadventure with electricity reform, however, has caused many jurisdictions to pause and reconsider. Mistakes in the design of California’s reform were exposed when stagnant capacity and extreme summer and winter weather combined to cause a tight market and skyrocketing wholesale prices for almost a year (mid-2000 to mid-2001).[8] The situation has since stabilised, but it remains to be seen whether California's debacle will stall the worldwide electricity reform movement. (See Box 3-2, page 92)

California's experience is an important reminder that while markets might be expected to outperform monopolies and state corporations, this is not guaranteed. The effectiveness of a competitive market depends on the soundness of its design and on the particular characteristics of each industry. Electricity is a special commodity in that supply and demand must be balanced everywhere on the grid at all times, and it has no substitute in today's information-oriented economies. This creates additional challenges for market design, because a tight electricity market can have much greater price and even reliability consequences than is the case with other commodities. While misinvestment and inefficient operation by electricity monopolies presents a substantial economic risk to society, inadequate controls and safeguards in a competitive electricity market also imply large economic risks from price shocks and power outages. Future efforts at liberalising the electricity sector must learn from the California experience.

The collapse in 2001 of the U.S. energy giant Enron provided another compelling signal of the potential downside of market liberalisation. When such a major energy corporation proves to be so vulnerable, potential reformers, especially in developing countries, may find it hard to justify the risks to their economy of aggressive liberalisation.

The benefits from some degree of liberalisation can be significant, and the movement to a greater role for markets will undoubtedly continue in spite of the California and Enron experiences. At the same time, the role of government and monopolies in the energy sector is likely to remain substantial and energy policies need to focus on improvements in this domain as well.

Improving Pricing, Regulation, and Management: Natural Monopolies, State Enterprises, and Public Agencies

In some situations, replacing public ownership and monopoly with private ownership and competition (i.e., moving right to left on the continuum in Figure 2-2) is the best way to achieve efficiency in the energy sector and make progress toward social development goals. In other situations, the best way may be to retain public ownership and monopoly while improving management practices (i.e., making improvements at a particular point in the Figure 2-2 continuum). Natural monopolies, state enterprises, and public agencies will continue to play a significant role in the energy sector, perhaps especially in developing countries, and there are significant opportunities to improve their ability to contribute to social, economic, and environmental sustainability goals. This section examines those opportunities, particularly in relation to natural monopolies, but many policies are equally relevant to state enterprises and public agencies.

Natural monopolies (private or public), state enterprises, and public agencies can become more effective and efficient via reforms that improve price setting, operating incentives, investment planning, and regulation. Indeed, much can be learned from the experiences of industrialised countries in regulating the investments and tariffs of natural monopolies, whether in electricity, natural gas, or oil pipelines. Application of similar innovations in developing countries may, however, confront various obstacles because often these practices are intimately tied to the legal, institutional, market, and cultural norms of industrialised countries.

Monopoly and State Enterprise Pricing that Reflects Costs

In sectors of the economy where natural monopoly and/or public provision of services are retained, pricing practices can be reformed so that the efficiency cost signals that markets provide are approximated. This involves two related objectives.

The first objective is to put the firm or agency providing the public service in a healthy financial position. The firm must earn enough revenue to cover operating and capital costs, including investment in system expansion as needed. The ability to expand is especially important in developing countries where electricity grids, communication networks, water supply systems, sewage systems, and transportation networks need to expand quickly. Yet it is usually in these countries that revenues are insufficient to cover system expansion and sometimes even operating costs. Not only are tariffs too low, some customers do not pay their bills – a common occurrence with state-owned enterprises in developing and transition economies. In the past, this revenue shortfall was covered in part by foreign aid in developing countries, by government operating subsidies in transition economies, and by growing debt in both. In recent years, however, debts have reached unsustainable levels, foreign aid for energy investment has declined, and governments are no longer able to fund ongoing energy subsidies. Thus foreign and domestic private investment are increasingly needed for both maintenance and expansion, but this will not be forthcoming unless an investor has confidence in receiving sufficient revenues to cover costs and to compensate for risk. Ensuring that prices reflect full costs is therefore a key objective.

The second objective in reforming the pricing practices of monopolies and public services is to design rates that more closely reflect the specific marginal costs of providing goods and services to different types of customers at different locations and at different times of day or season. The general principle of non-linear (or marginal cost) pricing is that a firm should set its prices to achieve two objectives: to earn enough revenue to cover total costs including a reasonable return on equity, and to set different prices that reflect incremental differences in cost of service.[9] In this way, the monopoly or public service approximates the economic efficiency signals that a competitive market might provide. This does not mean, however, that prices are only determined by economic efficiency; social considerations can influence the rate design process. For example, an inverted block electricity tariff sets low rates for base levels of consumption but higher rates for additional amounts in order to reflect rising marginal costs with expanded production. The low base charge also serves a social benefit by ensuring that poorer customers, who consume very little, pay less per unit. For this reason, inverted block rates are sometimes referred to as lifeline rates. Industrialised countries have made considerable progress over the past two decades in more closely aligning the rates of monopolies and state enterprises with costs. Developing countries have done less in this regard, and lifeline rates are rare. But there have been some encouraging examples, as in São Paulo, Brazil, where the local electrical utility charges a low rate for the first 50 kilowatt hours.[10] (See Box 3-4, page 109)

Efficiency-Promoting Regulation and Management of Monopolies and State Enterprises

Regulation of monopolies and state enterprises creates its own set of challenges and possible inefficiencies. Criticisms include:

- Lack of incentives for efficient management and operation.
- Inadequate external control over investment decisions.
- Capture of monopoly or state enterprise by interest groups.

In recent years, greater awareness of these problems has triggered market-oriented reforms, especially in the regulation of natural monopolies in industrialised countries. In what is referred to as price-cap regulation, the regulator fixes a tariff for several years and then allows the monopoly to determine the investment and operation path it will follow. Regulatory control is generally limited to ensuring that the monopoly meets specific quality-of-service obligations. The expectation of this approach is that the monopoly's efforts to reduce costs in order to maximise profits during the period between tariff settings (say five years) will provide a lower cost standard for setting tariffs for the subsequent period. In this way, the monopoly pursues some of the efficiency innovations normally associated with competitive markets.

Another possible market-oriented reform is to require competitive bidding, on a periodic basis, for the licenses to monopoly concessions. Bids can be required to include tariffs and other conditions of service. The few attempts at this approach have met with mixed results.[11]

Build-own-transfer and build-own-operate-transfer schemes are other approaches to encouraging private investment while retaining state ownership and control over the long term. The private developer makes an initial investment and earns a return on investment through some combination of revenue from government and commodity sales before transferring the facility to government. This approach has been used in various sectors, including electricity generation.

In some cases, the best approach may be to replace the traditional model of the large, centrally managed corporation with different institutions and relationships. In

Bangladesh, for example, rural electricity cooperatives have replaced the state electricity monopoly in several communities (Box 2-1). These cooperatives employ local people and have innovative rules to prevent corruption and promote efficient operation and, as a result, have achieved higher rates of bill payment and higher levels of service.[12]

Box 2-1
Rural Electricity Cooperatives in Bangladesh

Ineffective management and corruption result in revenue shortfalls that prevent electric utilities from providing reliable service and expanding their systems. Bangladesh has been notorious in this regard. In 1995, total electric system losses were 30 percent; this included normal electricity losses from power lines, poor maintenance and inefficient operation, and theft. Recent losses in comparable countries were China – 8 percent, Thailand – 9 percent, and India – 18 percent.

One bright light is the growing role for rural electricity cooperatives in Bangladesh – Palli Biddyut Samitees (PBSs) – operating under the guidance of the Rural Electric Board (REB). The PBSs had average system losses of only 13 percent in 1995, indicating dramatically better management and lower corruption than in the system as a whole. They also have a much higher rate of bill collection than the state-controlled utilities. These improvements have been achieved by a combination of financial discipline from the REB and community-level involvement in the PBSs.

The REB sets annual performance targets for PBSs and then conducts regular management and financial auditing. The REB also has authority to dismiss incompetent or corrupt managers. Managers of PBSs that meet their performance targets are awarded pay bonuses of up to 15 percent of annual income. Funding for system expansion is also linked to PBS performance.

The PBSs are non-profit distribution utilities partly owned by consumers. While they currently provide only 15 percent of total electricity sales in Bangladesh, their role is expanding. Their unique management practices include the following: 1) PBS board members are elected to office for a three year term, 2) meter readers are limited to three years in that function, and 3) billing assistant positions are reserved for women, which seems to have the effect of reducing dishonest practices.

Investment Planning for Monopolies, State Enterprises, and Public Agencies

In the absence of a market check on poor investments, natural monopolies, state enterprises, and public services need a planning framework to reduce the risk of misinvestment. In the North American electricity industry in the 1980s, massive misinvestments in generation plants motivated regulators and governments to institute a comprehensive investment evaluation and planning process called integrated resource planning (IRP).

IRP is simply a form of extended cost-benefit analysis that involves comparing alternative energy supply investments alongside energy efficiency investments for meeting a given level of energy service demand. Thus an electricity-generating coal plant would be compared with other supply options and with a campaign to motivate consumers to buy more efficient appliances (e.g., more efficient refrigerators as an alternative way of meeting the same level of food cooling service). Efforts to increase energy end-use efficiency are referred to as demand-side management.

Although integrated resource planning can differ in application, it generally involves the following steps:

- Identification of planning objectives.
- Forecasts of gross energy service demands.
- Identification of supply- and demand-side management options that together equal the forecast of gross energy service demands.
- Characterisation of supply- and demand-side management resources in terms of their economic, social, and environmental attributes.
- Creation of alternative portfolios of supply- and demand-side management options, each portfolio representing a particular set of preferences toward certain supply- or demand-side management options.
- Multi-attribute trade-off analysis leading to the selection of the preferred investment/program portfolio; analysis includes social, economic, and environmental objectives but may include additional objectives such as minimisation of the risk of dramatic price increases.
- An action plan to implement the preferred investment/program portfolio.

The popularity of integrated resource planning in the North American electricity sector peaked in the late 1980s. In the 1990s, its application to the assessment and planning of monopoly generation investments was superseded by the trend toward competitive generation markets. However, IRP is still used by many distribution utilities (gas and electric) to determine their demand-side management effort. Governments also use some of the same principles and methods when planning transportation systems or when determining public efforts in energy efficiency programs.

Integrated resource planning applications can range from a narrow consideration of financial costs to a broad consideration of externalities in the assessment of investment options. A later section discusses how cities can apply IRP in planning land-use, transportation infrastructure, and energy systems.

Subsidy Reform and Market Design to Mobilise Energy Investment

Market liberalisation purists argue that virtually no subsidies can be justified – that prices in energy and other sectors should reflect only the strict financial costs of production. But governments have long recognised that financial costs do not provide a complete picture of the benefits and costs to society from different activities. The public good rationale for energy market intervention has long been accepted to some degree by all governments, and the argument that externalities should be included in energy prices can be expected to grow in importance, as is discussed later.

In industrialised countries, the public good perspective has traditionally justified subsidies in the form of tax concessions and direct grants to conventional energy production, and in the form of cross-subsidies among the customer groups served by electricity and natural gas monopolies. With the recent trend toward liberalisation, however, monopolies have reduced or eliminated such cross-subsidies and governments have decreased their direct support to conventional energy. Nonetheless, subsidies to conventional energy are estimated at about US$150 billion per year worldwide as of the late-1990s, many of them in industrialised countries.[13]

In centrally planned and developing countries, there has been less interest in ensuring that energy prices reflect the financial costs of production; in essence, the public good rationale has dominated. Significant cross-subsidies were combined with subsidised capital from government (i.e., capital that does not receive a full return on the investment). In addition, developing countries received investment capital in the form of foreign aid (loans and grants).

In developing and centrally planned countries, the public good rationale motivated national governments and aid agencies to focus investments on energy supply megaprojects as a key tool of economic development. This followed the earlier strategies of countries like the United States, which subsidised major hydropower developments in the northwest (Bonneville Power Authority) and the Appalachian region (Tennessee Valley Authority) in the 1930s while also subsidising electrical grid extension into rural areas.[14]

The experience in developing and centrally planned economies, however, has not been as positive, demonstrating just how difficult it is to find the right balance between government financial support and the economic efficiency that markets can foster. Many subsidies and government interventions in these economies have fallen far short of economic development expectations, and are instead associated with:

- Inefficiently operated public utilities and state enterprises (sometimes including considerable corruption).
- Poor quality of service with frequent power outages.
- Poorly conceived and executed energy megaprojects resulting in wasted capital resources.

- Ongoing subsidies to commercial energy consumption that reduce government's financial ability to pursue other social development goals and, in any case, do not reach the poorest members of society in developing countries.
- Unjustifiable cross-subsidies between energy utility customers.
- Inability to generate new energy investment from internal revenues.
- Inability to attract new energy investment from aid agencies or private investors.

Developing and transition economies today face the daunting task of dramatically improving energy system operation while also mobilising massive new investments in energy supply and delivery. Not surprisingly, governments of these economies are now more amenable to arguments that a greater role for markets is needed. At the same time, however, the lessons from the earlier strategies and experiences of industrialised countries should not be forgotten. Developing and transition governments must find a balance between a greater reliance on markets for energy investment and an effective mix of policies supporting social development that would otherwise be ignored by the market.

How large is the challenge? Although estimates vary, the average annual level of global energy investment of the last decade – US$300 to US$400 billion (US$ 1999) – must be maintained for several decades if adequate energy services are to be provided to the planet's current and future inhabitants.[15] This is about 10 percent of total global investment. Multilateral and other official lending institutions are unlikely to provide more than a small percentage of the capital needed in developing countries where local capital resources are severely limited.

What strategies are available? The governments of transition and developing countries have increasingly realised that subsidies to conventional energy consumption need to be dramatically reduced. Reducing or eliminating subsidies provides internal revenues for investment, improves the prospects of attracting direct foreign investment, and improves the financial capacity of governments to pursue other development objectives. Underpricing of electricity, for example, is estimated to have cost developing countries US$130 billion per year in the early 1990s. Since then, however, many countries have significantly reduced their subsidies. Between 1991 and 1996, China cut fossil fuel subsidies in half while Russia reduced them by two thirds.[16]

In some cases, the better strategy may be to retain some subsidies, but apply them with greater attention to financial, social, and environmental sustainability. Subsidies can be used in a number of ways. These are discussed here in terms of the needs of developing and transition economies, but the principles apply equally to industrialised countries.[17]

- Sunset clauses can be used to reduce the risks that certain groups will become dependent on the subsidies. Ideally, the sunset clause should have a gradual schedule for reducing the subsidy – stated at the outset – to ease the transition away from the subsidy program.

- Subsidies can provide access to commercial energy but should not subsidise its consumption. Thus, in situations where electric grid extension is socially beneficial, subsidies can provide one-time assistance for the grid extension investment but should not provide electricity price relief. Otherwise the financial demands on the government or public utility will quickly get out of control as incomes and demand increase. In situations where the development of a local energy system does not entail connection to the grid, subsidies should still relate to access and not consumption (e.g., help with the start up costs of a local photovoltaic, small hydro, or biomass energy system). For both on-grid and off-grid subsidies, a competitive bidding process can increase the subsidy's cost-effectiveness. Recent innovations along this line in Argentina are noteworthy.[18]

- Subsidies should be redirected from supporting conventional energy forms to providing access to clean energy forms and technologies. Modern renewable technologies are generally easier to categorise. Discussed later is how the full consideration of environmental externalities might influence which type of technology or form of energy to support.

- Modest government support can help rural small businesses and rural households increase their access to energy investment financing.[19] Such financing could help small-scale producers obtain needed capital for infrastructure or other investment, or help households purchase more efficient and clean-energy-using equipment. A frequently cited example is the Grameen Bank of Bangladesh, whose energy division lends money for small-scale wind and photovoltaic schemes.

- Similarly, government can support energy-efficiency efforts either by providing direct financing to firms and households for energy-efficiency investments, or by supporting energy service companies that then market energy-efficient technologies and practices.

- Finally, it is increasingly recognised that a critical component of economic development is government support for training and other forms of capacity building in the energy sector. Without trained personnel, the prospects for new, clean energy technologies are much less positive.

The development of competitive markets, and the attraction of private investment (foreign and domestic) to the energy sector, requires other changes in addition to correcting subsidies. As the experience of the transition economies over the past decade shows, attracting energy sector investment also depends on a broad series of fundamental legal, institutional, and social reforms and developments. These reforms are difficult to achieve and could take a long time. The reforms needed include the following measures that may be new in developing or transition countries but tend to be taken for granted by citizens of industrialised market-economy countries:

- Full property rights for private consumers and producers.
- Free consumption choices for consumers.
- Adequate information for consumers and producers.
- A legal system regarded as impartial and independent of government and interest groups.
- An effective and transparent market system for executing and enforcing energy transactions, including currency convertibility, freedom to remit dividends, and a stable domestic savings and investment regime.
- Political and economic stability.
- A regulatory regime (natural monopoly regulation, securities regulation, financial institution regulation, etc.) that promotes competition and efficiency and is independent of government, as well as transparent, predictable, and stable.
- Removal of all energy subsidies except those justified under an open social costing process.
- Substantial reduction of barriers to international trade and investment.
- Interest-group associations that can develop technical skills and other aspects of capacity building, as well as participate in energy policymaking.
- An independent and responsible media.

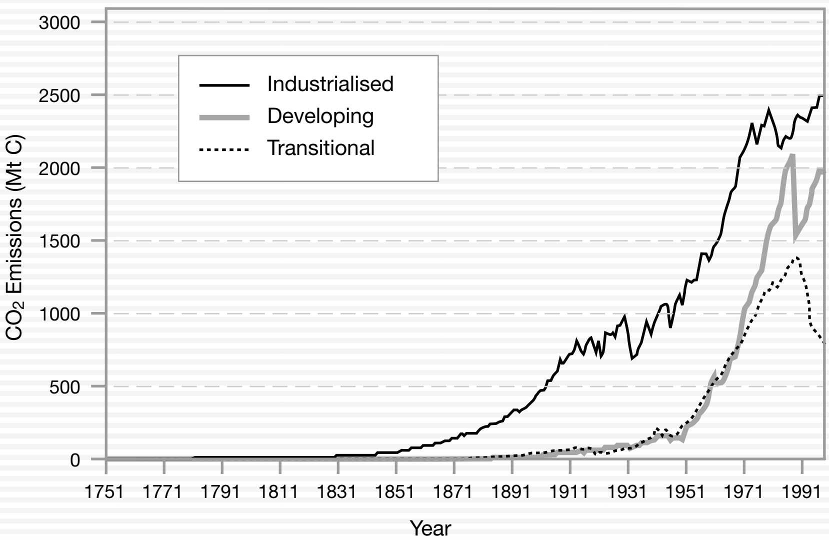
Addressing Externalities with Minimal Government Intervention

As already noted, environmental externalities are a growing challenge requiring some form of government intervention. While commercial energy systems have productivity and indoor health advantages over many traditional energy technologies and energy sources, current energy systems are far from sustainable. Figure 2-4 shows the increase in CO_2 emissions for industrialised, transition, and developing countries from 1750 to the present.

Discussed below are efforts to improve markets by internalising negative externalities, especially environmental externalities.[b] This section focuses on policies that seek to minimise government intervention in the market by relying on information and pricing policies (the left side of the continuum in Figure 2-2). The subsequent section describes policies relevant to areas in which the government

[b] A general term for the analysis behind such policies is social costing, which is defined as the combination of private financial costs (those capital and operating costs normally seen in the market) with uncompensated negative externality costs.

FIGURE 2-4: HISTORICAL CO_2 EMISSIONS (1751–1998) BY TYPE OF ECONOMY



Notes: **Industrialised** includes North America (excluding Mexico) and the industrialised countries of Europe. **Transitional** includes the centrally planned states of the former Soviet Union and Eastern Europe. **Developing** describes the remaining countries; includes Africa, Asia, Latin America, and Oceania.

Sources: Compiled from data in G. Marland, T.A. Boden, and R. J. Andres, 'Global, Regional, and National Fossil Fuel CO2 Emissions', in *Trends Online: A Compendium of Data on Global Change* (Oak Ridge, TN: Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, 2001). Accessed on-line at cdiac.esd.ornl.gov/trends/emis/em_cont.htm, December 20, 2001.

retains a dominant role, such as urban planning, or in which highly interventionist regulations are still preferred (the right side of Figure 2-2). Then comes a section discussing emerging hybrid policies that combine regulation with the flexibility normally associated with market-oriented pricing policies (the middle of Figure 2-2).

Which of these three broad approaches is most applicable depends on factors such as:

- Which approach is consistent with the economic development dynamic (institutional reform, market reform, fostering foreign and domestic investment, technology transfer, etc.) of a particular society.
- Which can best adapt to the different levels (sometimes dramatically different) of technological and commercial development within a country.
- Which is most appropriate for a country's new-technology development and dissemination strategies.

- Which is most consistent with international sustainability efforts and mechanisms (the Clean Development Mechanism of the Kyoto Protocol, international tradable permits, etc.) and international trading relationships (not vulnerable to claims of unfair trading practices, etc.).

Strategies seeking to affect prices with minimal government intervention include imposing emission taxes, providing fiscal incentives to adopting environmentally friendly technologies, and providing information and ethical arguments to promote behaviour change.

Emission Taxes

Economists have argued for some time that setting a tax per unit of emission equal to the marginal value of externality damages would lead consumers and firms to reduce emissions to where the marginal cost of further emission abatement equalled the tax. This approach has not been widely used, but it has garnered support from environmentalists and even politicians in some countries.[20]

Emission taxes have several apparent advantages.

- They work in concert with the normal efficiency incentives of the market. The taxes maintain a continuous incentive for innovations that reduce emissions and thus reduce tax costs, even for firms with low emission levels.
- Emission taxes are sensitive to the heterogeneity of equipment types and ages. If every plant faces the same emission reduction requirement, some plants are likely to have higher costs than others. The total cost to society of achieving an aggregate level of emission reduction is minimised if each plant reduces emissions to where the cost of the last unit reduced is equal for all plants (called the equi-marginal principle). Because a tax gives a uniform pollution cost signal throughout the economy, each plant is motivated to reduce emissions to where its marginal cost of reduction equals the tax rate; no reallocation of reduction contributions can reduce the total cost to society of achieving the aggregate emission reduction.
- Emission taxes avoid involving governments in judgements about technological choice or individual behaviour. Each member of society pays emission fees based on the amount of pollution they cause but they are not prohibited from these pollution-causing activities. Some members of society will do more to reduce pollution and others less (the latter paying more taxes) by choosing their preferred behaviour and technology under the tax, but society will achieve emission reductions in aggregate.

Emission taxes also present significant implementation challenges, some of which can be decisive in determining whether they are utilised in some societies.

- Correcting prices to reflect pollution damages may have negligible or even distortionary impacts if the original prices do not reflect costs (perhaps because of heavy subsidies) or if investment decisions are not based on real input costs and product prices. Emission taxes should reflect the monetary value of marginal damages, but the estimation process is fraught with uncertainties. Despite wide-ranging estimates, there is increasing recognition that at least some minimum value for externality damages is better than no value. Recent analysis by Europe's ExternE program shows cost estimates for coal externalities ranging from 1.6–8 cents per kilowatt hour (US$) and for nuclear from 0.2–2.3 c/kWh.[21]

- Even if the tax accurately reflects the marginal value of damages, market participants might not adjust their emissions to the extent necessary to produce the environmental or social outcome that those same people would have chosen through political processes had they been well informed about all costs and risks. Collective preferences for sustainability may differ substantially from the aggregate outcome of individual consumption decisions in the market. For this reason, some analysts argue that in setting environmental and social sustainability objectives, we need to develop methods of eliciting informed public preferences about environmental and social outcomes.[22] Based on this information, governments could experiment until they found the tax level that achieved the environmental target.

- The specific relationship between emissions and environmental harm in a given location may require more refined policies than can be achieved with emission taxes. Acceptable levels in each locality might only be attainable with an absolute maximum emission level for each plant.

- The social impacts of implementing taxes, even gradually, may be unacceptably high for some consumers or industrial sectors. Politicians will be under extreme pressure either not to impose taxes or to provide exemptions that work against the equi-marginal principle. In response, some advocates of emission taxes have focused on tax reform in which the imposition of emission taxes is combined with reductions in other taxes – referred to as environmental tax shift or environmental fiscal reform.

Fiscal Incentives

Instead of reducing subsidies to *conventional* forms of energy (discussed earlier), an alternative way of changing market signals is to provide subsidies (fiscal incentives) to *environmentally desirable technologies*. Such incentives include investment grants, investment tax credits, and guaranteed prices for supplies from certain technologies. In the 1990s, England's Non-Fossil Fuel Obligation used revenue from a charge on all electric grid users to provide grants to investors in windmills and other favoured technologies. The U.S. government provides an investment tax credit for windmill investments, and the German government guarantees a minimum price for electricity generated by windmills.[23] Brazilian electric utilities are required to spend 1 percent of their revenue on electricity efficiency programs. At the international level, the Global

Environment Facility and the Clean Development Mechanism of the Kyoto Protocol are examples of mechanisms designed to transfer funds from industrialised to developing countries in order to support investments in cleaner energy technologies.

Fiscal incentives have similar strengths to emission taxes.

- If designed properly, fiscal incentives can be consistent with the cost-minimising intent of the equi-marginal principle; for example, incentives can be designed to reward technologies with the lowest required level of subsidy, thus providing a continuous incentive for cost-reducing innovations.
- Fiscal incentives do not encounter the political reaction of tax increases. Of course, fiscal incentives are ultimately funded by government revenue – which is primarily generated from taxes – but this link between incentives and taxes is unclear and therefore less prone to generate a negative political reaction.
- It is relatively easy to attach fiscal incentives to a cost-reducing and commercialisation strategy for specific technologies – mass production leading to economies of scale and economies of learning in manufacture, dissemination, and installation.[24]

As noted in the earlier discussion on subsidies and conventional energy, the challenge in using fiscal incentives is that their application can be inefficient, unsustainable financially, and yet difficult to eradicate once certain groups are dependent on them. Fiscal *disincentives* could also be misapplied if they are not directly attached to the cause of environmental harm. For example, while greenhouse gas taxes would only apply to net harmful emissions, fuel taxes based on energy content would inadvertently penalise alternative fuels like ethanol that in their lifecycle of production and consumption may not entail net increases in atmospheric greenhouse gases. Finally, the ability to effectively apply fiscal incentives and fiscal disincentives depends on a given economy's level of market development.

Information and Ethical Arguments

A third approach on the left side of the Figure 2-2 continuum is to provide information and ethical arguments to change how firms and households respond to current prices. This approach does not involve changing market prices.

Governments can and do present ethical arguments that firms and households should adjust their market behaviour to reflect full social costs even though they face higher financial costs in doing so. To this end, governments may lead by example and encourage others to follow. Governments can take action in those sectors of the economy where they have direct ownership or management responsibilities (e.g., state-owned corporations, public lands, public buildings) while trying to convince other members of society – consumers, labour organisations, shareholders, and business managers – to also take voluntary actions. Interest groups and government can encourage consumers to include environmental and social performance alongside financial cost in their purchase decisions via green marketing, eco-labelling, and even product boycotts. Labour organisations can incorporate environmental and social objectives in their contract negotiations. Investors can support ethical funds that rank corporate performance on financial, environmental, and social criteria, and this *triple-bottom-line* approach could in turn dominate the management strategies within corporations.[25]

Governments also present financial self-interest arguments in favour of energy- and material-conserving investments. Operating costs savings due to improved energy and material productivity can more than compensate for the additional capital cost of efficient technologies. Governments can provide firms and households with information on profitable investment opportunities and behavioural changes that coincide with environmental and social objectives via product labelling, advertising campaigns, and demonstration projects. Some advocates of this approach suggest that this can take the global economy far down the road toward sustainable development.[26]

Whether the motive is altruistic or financial self-interest, a policy that influences the decisions of firms and households without incurring the unpopularity of increased prices or harsher regulations appeals to governments, industries, and consumers. However, some analysts are suspicious of the effectiveness of this approach, at least if undertaken without a package of complementary financial and regulatory policies.

First, ethical values may be ephemeral. Consumers' preferences and ethical considerations in industrialised countries change quickly, as people's focus shifts from one issue to another. Also, if the technology or fuel with the higher environmental benefit costs more in the short run than the environmentally harmful one, choosing the environmentally friendly technology may simply be too costly for the half of the world's population that is extremely poor.

Second, the financial benefits of energy efficiency investments are under dispute. Some researchers find that energy efficiency investments are lucrative, meaning that environmental targets like reducing greenhouse gas emissions are relatively inexpensive.[27] Other researchers criticise the assumption that differences in financial costs among technologies (at the social discount rate) are sufficient for estimating the full cost of switching to more energy efficient (and less greenhouse gas emitting) technologies. They argue that technologies may differ in ways that are not represented by the financial analysis approach. For example: 1) new technologies are likely to be riskier; 2) there may be a value to delaying or avoiding irreversible investments with long payback periods, such as energy efficiency investments; 3) technologies that are apparent substitutes may be valued differently in some way by consumers (incandescent lights may be preferred to compact fluorescent lights for some qualitative reason); and 4) not all firms and households face the same costs so market outcomes will be variable.

From a perspective of making markets work better, this dispute is important. One side is willing to countenance regulation in favour of energy efficient technologies while the other argues that consumer costs and ultimately political costs could be much more significant than assumed. At least both sides support greater information provision by government and agree that some fiscal means of internalising negative externalities is necessary at a minimum.

Addressing Externalities through Improved Regulation and Planning

The right side of Figure 2-2 depicts situations in which the role of the market in resource allocation is substantially restricted by regulations or is replaced by the decision making of monopoly managers and planners. In such cases, there are nevertheless opportunities to introduce some of the efficiency and flexibility characteristics of markets.

Regulations and the Market

Regulations are legal requirements with prohibitive penalties that force firms or households (or lower levels of government) to make specific technology or behaviour choices or to produce only certain products. Early approaches to environmental protection – called command-and-control – frequently applied regulations to force producing firms to acquire pollution-control equipment or not to exceed levels of emissions or effluents.

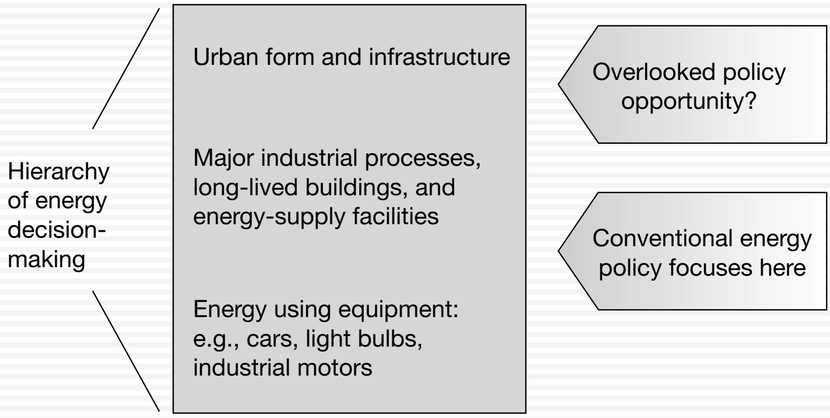
Regulations are sometimes presented as fair and effective. They can be fair in that the same technology or performance requirement applies to every comparable plant or firm. They can be effective in that, by prescribing a specific technology or behaviour, they ensure a specific outcome in terms of the level of pollution, which is especially important with highly toxic substances. However, regulations can also be unnecessarily expensive to the extent that they transgress the equi-marginal principle; they do not allow firms the flexibility that would reduce the total costs of achieving an environmental target. Another concern is whether or not regulations will be applied fairly and effectively, as the establishment and enforcement of regulations provide opportunities for corruption.

A recent argument in support of regulatory approaches is that they can motivate firms to come up with innovative, productivity-improving responses that create a future competitive advantage for the economy that implements the strictest regulations first. To be successful, however, such regulations must correctly anticipate trends in resource costs and environmental standards, and they must be designed to reward innovation by focusing on outcomes not specific technologies.

Community Energy Management

The application of integrated resource planning to the regulation of energy monopolies, especially in the electricity sector, was discussed earlier in this chapter. The benefit of this approach is that it makes the energy decision making process more transparent and improves the consistency with which intangible values and risk perceptions influence that process. IRP principles can also be applied more broadly to various aspects of public decision making with respect to urban form, energy, and the

FIGURE 2-5: HIERARCHY OF ENERGY DECISION MAKING



environment. While energy analysis and policy has traditionally focused on technology choices – both energy-using and energy-producing – these choices are made within a physical context of buildings, designated land uses, and infrastructure. Figure 2-5 shows this hierarchy of decision making, with land use and infrastructure at the top and individual energy-using equipment at the bottom.

Community energy management (or community energy planning) involves a process of comparing the infrastructure, energy supply, and environmental/social effects associated with alternative evolutionary paths for urban form and infrastructure. A deliberate effort to include energy considerations at the community land-use zoning and infrastructure-planning level can affect energy use and the resulting social costs, even over a relatively short time of one or two decades. Mixed land use decreases travel distances to work and shopping. Coordination of high density with public transit reduces the need for individualised transport such as taxis and personal vehicles. Integration of residential housing with commercial and light industrial activity increases the opportunities for efficient district heating and cogeneration of heat and power.

Until recently, policy makers in most countries have largely overlooked the potential contribution of community energy management to sustainable energy policy. This is especially true in North America and in developing economies. In contrast, northern European countries have been practising a form of community energy management for decades, as is evident in the high rate of transit use, penetration of district heating, and overall low per capita energy use in their cities relative to urban areas of comparable wealth and climatic conditions in North America.

The countries of the former Soviet block and China practised centralised urban planning for decades, which included integrating light industry, residential and commercial activities, development of public transit, and cogeneration of electricity and heat for residential, commercial, and industrial users. In the coming years, these systems, which are sorely in need of upgrading, must adapt to the evolution of urban form as an increased role for markets brings greater freedom of choice. Practitioners of community energy management will need to demonstrate the attractiveness of integrated residential and commercial activities along with providing affordable housing and safe, quick, and reliable public transit. Greater use of individualised energy metering and billing is also likely as private investment plays a growing role.

Community energy management is especially important to developing countries, as these will experience overwhelming urbanisation in the next decades. By 2020, most of the population of developing countries will live in urban or peri-urban areas surrounding major centres. China, for example, will experience a move to the cities by several hundred million people; the environmental effects of a community energy management strategy can therefore be profound.[30] As the interest in this approach to energy sustainability grows, some cities, such as Curitiba in Brazil, serve as models for the kinds of policies that can be successful (Box 2-2).[31]

Box 2-2
Community Energy Management in Curitiba, Brazil

While the rapid urbanisation in developing countries presents monumental challenges, it also provides unique opportunities. A myriad of incremental, and seemingly unimportant, decisions about urban land use and infrastructure taken today will profoundly determine the ability of tomorrow's burgeoning urban centres to achieve sustainable energy systems. Curitiba, Brazil, provides an example of how effective planning can have a positive impact on a community's development.

Now a city of over two million, Curitiba has, since the 1970s, channelled growth along five axes radiating from the city centre. Each axis has a bus expressway and parallel roads for vehicles. Land use zoning has concentrated high-density development to the five axes, especially centred on interchange bus terminals that are located about every two kilometres along each axis. Passengers from lower density areas take feeder buses to these terminals, where they transfer to the express buses for travel to the city centre.

Costing about 1/200th per kilometre of a conventional subway system, the bus expressway nonetheless achieves comparable performance in terms of ridership and travel times. While Curitiba has a high rate of car ownership for Brazil, almost 75 percent of commuters use buses, resulting in 25 percent lower vehicle fuel consumption than similar Brazilian cities. Reduced fuel consumption contributes to the city's relatively low level of urban air pollution, and reduced vehicle use for commuting fosters a more pedestrian-oriented city centre. The express bus system is operated primarily by private companies under guidelines from, and in partnership with, the municipal government.

Addressing Externalities through Market-Oriented Regulatory Approaches

Because they are not compulsory, non-interventionist and market-focused approaches to addressing externalities have a lower chance of achieving environmental targets. They may also be politically challenging if they entail significant price increases. Regulatory, interventionist approaches have a greater chance of achieving environmental targets but can be costly and may therefore also be politically difficult. In recent years, emerging hybrid policies combine aspects of both. The discussion below is divided into property rights and market-oriented regulatory approaches to these hybrid policies.

Assigning Property Rights

Economists agree that markets function best when property rights are clear and legally secured; it is difficult to trade if either party is unsure of ownership. One suggestion, therefore, is to assign some form of property right to common property resources, as these are frequently the focus of environmental damage. In the ideal, this assignment of property rights would enable parties to use the legal system to determine the appropriate compensation for emission damages and even set the appropriate level of emissions. In practice, this approach faces a number of challenges.[32] First, the initial assignment of property rights has implications for the distribution of wealth and thus for the efficient outcome. Those who are initially awarded the property right to the common property resource experience an increase in real income that may affect their willingness to trade. Second, some parties (such as a coalition of affected parties) may face high transaction costs (costs of coordinating and trading) for use of the legal system and this too will affect the outcome. Third, property rights are difficult to establish and enforce in parts of the world, and their establishment may cause other undesired cultural and social problems.

Because of these and other challenges, full property rights to common property resources have rarely been assigned as a means of allowing individual members of society to determine the appropriate level of emissions. The idea of assigning property rights can, however, be applied in a less ambitious manner. Once society establishes – via some mechanism of public choice – the desired target level of emissions, then the rights to fixed levels of emissions can be allocated, with trading allowed in order to achieve the target as efficiently as possible. This is referred to as *flexible instruments or market-oriented regulation*.

Market-Oriented Regulation

Market-oriented regulation is a form of regulation in that the aggregate target, such as an economy-wide emissions cap or a level of technology market penetration, is compulsory. All firms and households are implicated and non-compliance incurs prohibitive financial penalties. Market-oriented regulation is unlike traditional command-and-control regulation, however, and more like an environmental tax, in that the manner of participation is at the discretion of the firm or household. Some may contribute to achieving the aggregate target by reducing emissions or acquiring the designated technology, while some may instead pay others to do more in order to make up for their unwillingness to reduce emissions or acquire the technology.

The best-known example of a market-oriented regulation is the cap-and-tradable-permit mechanism. This is a regulation that sets a total emission limit, or cap, for whatever entity is being regulated—several firms or an entire country or the globe. Shares of this emission limit are allocated as permits by some method (historical levels, auction, or some combination of these) to individual participants. The shares provide a specified right to pollute that can be traded like any property.

The cap-and-trade regulation has attractive features:

- The cap ensures that the environmental target will be achieved.
- By allowing trading among participants, the cap-and-trade regulation functions like a tax in providing a uniform cost signal – the permit trading price – to all participants and thus applying the equi-marginal principle for cost-minimisation.
- A positive permit price ensures a continuous incentive for further innovations that reduce specific emissions.
- Government can increase the allowed level of emissions if permit prices are unacceptably high by selling additional permits, while government and anyone else (environmental advocates for example) can reduce the level of emissions by buying some of the permits and not using them.

The most noteworthy application of cap and tradable permits started with the amendments to the U.S. Clean Air Act in 1990. Sulphur emissions from specified electricity generation plants in the United States were subject to a cap-and-tradable-permit regulation, with a first phase from 1995 to 2000 and a second more ambitious phase after 2000.[33] This program resulted in substantial reductions in emissions and the total cost of reduction was much lower than anticipated, in part because the cost of sulphur scrubbers fell substantially between the announcement and implementation of the policy. Changing rail tariffs, and hence an opportunity for longer distance transport of low sulphur coal, also played a part, supporting the argument that the flexibility of market-oriented instruments will lead to unanticipated cost reductions, exceeding those of a technology-specifying, command-and-control approach (Box 2-3).

The U.S. sulphur-permit trading policy inspired a growing number of similar experiments in the United States and elsewhere. These are usually focused on the control of emissions; thus it is the emission itself that is capped, permitted, and traded. However, the approach can be generalised beyond emissions to regulations that specify some other attribute, such as the type of technology or the form of energy

Box 2-3
The U.S. Sulphur Dioxide Permit Trading Program

Tradable emission permit programs combine aggregate-level regulation with market-like flexibility for the individual firms (or possibly households) under the program's ambit. Regulation at the aggregate level fixes the maximum allowed emissions (a cap), and this total is allocated by some criterion (historical emissions, auction, or a combination of these) among participants as emission permits. The market-like flexibility is achieved by defining the emission permits as tradable property, in effect a tradable right to pollute. Participants decide on the basis of self-interest how much to reduce emissions and whether to buy or sell permits. A positive trading price for permits provides a continuous financial incentive for technological innovation and new practices that reduce emissions and thus free up allocated permits to sell for profit in the permit trading market.

The U.S. government's sulphur dioxide (SO_2) program is the most ambitious application of the cap-and-tradable-permit approach. Detailed analysis and policy debates about acid rain during the 1980s culminated in amendments to the U.S. Clean Air Act in 1990. These amendments established a cap for SO_2 emissions 50 percent below 1980 levels by the year 2000 and about 70 percent below by 2010. Phase I (1995–2000) allocated emission permits among 110 coal-fired electricity plants in the eastern United States based on historical emissions and fuel use. A small number of permits were also auctioned annually by the U.S. Environmental Protection Agency, but the total available permits decreased each year, thus lowering total emissions in order to meet the cap. Permits held in excess of emissions could be banked for future years. Emissions in excess of permits (whether initially allocated or purchased) triggered a fine of US$2,000 per ton. Phase II (beyond 2000) extends the programme to virtually all existing and new fossil-fuelled electricity plants in the continental United States and lowers the emission cap.

Observations from the early years of Phase I show emission reductions exceeding the annual target at costs well below expectations. The average cost of emission reductions was about US$190 per ton, whereas pre-programme estimates had suggested US$300 per ton. The permit trading price, which should reflect incremental instead of average costs of emission reduction, was initially in the US$300 range but soon fell to the US$100 to US$200 range, well below almost all pre-programme estimates, some of which had been as high as US$1,000 per ton. By some estimates, the cap-and-tradable-permit programme saved close to US$1 billion per year in its initial years, a 30 to 50 percent reduction over the anticipated costs from a conventional command-and-control regulatory approach. These remarkable results are explained by the flexibility of the cap-and-tradable-permit approach and the provision of sufficient lead-time between announcement of the programme and the implementation date. Half of early cost reductions resulted from innovations in SO_2 scrubbing technology, and the other half resulted from plants switching to low sulphur coal (a result of falling costs of coal transportation due to deregulation of railway tariffs).

that is used. Government sets a minimum regulatory requirement for the market share of certain technologies or forms of energy, and then allows market participants to trade among themselves to meet that requirement. Two noteworthy innovations, described below, are the renewable portfolio standard in electricity generation and the vehicle emission standard in the automobile sector.

A growing number of jurisdictions in industrialised countries (Europe, North America, and Australia) have implemented the renewable portfolio standard (RPS) in electricity.[34] RPS requires electricity providers (or purchasers) to ensure that a minimum percentage of electricity sold in the market is produced by wind, solar, biomass, small hydro, or other designated renewables. To minimise total costs, electricity providers can trade *green certificates* (certified output of renewable electricity) among themselves in the same way that tradable pollution permits are traded.[c] There is no guaranteed price for renewable electricity, only a guaranteed market share. This sustains the competitive pressure for cost reductions because any reduction in the cost of producing renewable electricity will lead to higher returns and/or larger market share for the individual renewable producer. Because each purchaser of electricity is paying a blended price, comprised of the new renewables along with the dominant, conventional supply, the RPS has a negligible effect on rates. RPS targets are modest initially, giving time for the market to adjust and for competitive pressures and commercialisation to drive down the cost of new renewables.

Governments have traditionally supported renewables with grants for research and development, supply price subsidies, tax credits, and information and voluntary programs. If desired, these can be retained alongside the RPS. This type of policy may be especially well suited to developing countries because the requirement can be applied initially to a public monopoly and then transferred to all market participants if the intention is to reform toward a competitive market. China has recently initiated the development of a renewable portfolio standard as part of its tenth Five-Year Plan.

A similar policy – this one focused on technologies instead of energy forms – is the vehicle emission standard (VES). The VES requires automobile manufacturers to guarantee that a minimum percentage of vehicle sales meet different categories of maximum emission levels.[35] The policy originated in California around 1990 and is the central focus of that state's efforts to improve local air quality. It allows manufacturers to trade among themselves in achieving an aggregate target; this flexibility lowers the cost of achieving the emissions reduction goal. The policy also gives manufacturers considerable lead-time between target setting and firm target dates, again to improve the prospects for cost reduction. Implementation of the VES has not been without challenges, however, especially in the negotiations and debates surrounding the zero emission category, and some deadlines may yet be renegotiated. But the California VES seems to have played a significant role in the recent emergence of revolutionary new vehicle technologies, notably electric-gasoline hybrids, battery-electric, and fuel

[c] RPS is sometimes referred to as a green certificate market in Europe.

cell-electric vehicles (Box 2-4). Manufacturers now aggressively compete to capture this new market, and this competition is reflected in recent research funding, commercialisation efforts, and marketing strategies. New York, Massachusetts, Vermont, and Maine have copied the California legislation. As with the RPS, the VES could be implemented in developing countries; indeed, negative social effects should be minimal given that vehicle ownership is limited to the highest income groups in most developing countries.

Box 2-4
The California Vehicle Emission Standard

The market-like flexibility of a tradable emission permit programme is now being emulated by environment policies that focus on technology characteristics rather than on emissions themselves. One such policy specifies minimum market shares for categories of vehicles that comply with maximum emission limits, while allowing manufacturers the flexibility to trade among themselves in meeting these minimum market shares. California leads policy development in this area.

The California Air Resources Board (CARB), a quasi-independent regulatory agency, sets state standards for vehicle emissions. In 1990, CARB adopted new requirements that established minimum market shares for low and ultra-low emission vehicles with phase-in target dates between 1994 and 2004. In 1999, CARB adopted a more aggressive programme that included super-ultra-low and zero emission vehicles, with phase-in dates between 2004 and 2010. Manufacturers may be fined US$5,000 per vehicle for not meeting their minimum market share requirements; however, manufacturers can trade credits among themselves so that non-compliance by one can be offset by over-compliance by another. There is also some flexibility in the timing of compliance. A growing number of other states, such as New York and Massachusetts, have tied their vehicle standards to California's. Other countries are also looking closely at California's standards. While CARB's standards currently focus only on local air quality objectives, California legislators are considering broadening the standards to include greenhouse gas emissions.

Vehicle emission standards are controversial. Manufacturers have argued that standards force them to design and build expensive and unmarketable vehicles. Advocates of standards paint a different picture. Standards mobilise producers to make the long-term research and development effort needed for fundamental technological innovation without significantly increasing current vehicle prices. They reduce the costs of new technologies by: 1) giving manufacturers longer lead-times for developing new technologies, 2) guaranteeing the production levels necessary for realising economies of scale and economies of learning, and 3) allowing compliance flexibility through market-like trading instruments. Minimum market share standards motivate producers to rethink their marketing strategies in order to capture any value from consumers related to the desirable attributes of the new vehicle technologies. While the evidence is not conclusive, it appears that the California standards have had a profound impact on vehicle design at a cost much lower than originally suggested by sceptics. Many analysts attribute the recent development of new vehicle technologies such as battery-electric, electric-gasoline, and fuel cell vehicles to the California standards.

These three market-oriented regulations – emissions cap and trade, RPS, and VES – are of special interest for the development of a sustainable energy system for several reasons.

- By providing an adequate time frame along with firm deadlines and penalties, these policies can mobilise producers to make the long-term research and development effort needed for fundamental technological innovation.
- The policies intervene at the nexus of new product development and mass commercialisation. Research on technology diffusion indicates that technology costs can experience a dramatic decline once the scale of production surpasses critical thresholds, which is more likely with a guaranteed market share or a guaranteed level of emission reduction.[36]
- The policies reduce costs by allowing producers the flexibility to trade among themselves in achieving the aggregate, regulated outcome.
- The policies provide an incentive for producers to rethink their marketing strategies; if producers can convince consumers to pay a premium for the value they receive from renewable electricity or low emission vehicles, the financial benefits to producers increase.[d] The result is to mobilise producers to market *greenness* to consumers.
- The policies can be directly linked to the environmental target. Thus Denmark and the Netherlands pursue the RPS as a key component of their greenhouse gas objectives, and California links the VES to its local air quality goals.
- The policies apply to just one sector of the economy, which reduces negotiation challenges and increases the chance of policy support. At the same time, applying a different policy instrument and target to each sector of the economy increases the risk of transgressing the equi-marginal principle by undertaking high cost emission reductions in some sectors while ignoring lower cost options in others. Pre-implementation assessment, combined with post-implementation monitoring and adjustment, should reduce this risk.
- The policies provide key social cost signals to producers but have minimal effect on average consumer prices, which increases the chance of political acceptability. Because electricity prices in the United States generally reflect average production costs, the higher marginal costs attributable to sulphur emission reduction were blended with all other costs, with negligible upward effect on average prices. Similarly, electricity prices and vehicle prices would be minimally affected by the RPS and VES given that the higher costs of renewable electricity and cleaner vehicles would be averaged with the dominant conventional electricity generation and vehicle production costs. Sales under the RPS and VES will initially be a small percentage of the total sales of electricity and vehicles.

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[d] This is less important for policies that affect only the choices of producers, which is the case with the sulphur-emission cap-and-trade policy for U.S. electricity generators.

In spite of these attractions, these types of policy instruments are still in their infancy and their full potential is difficult to predict. They also present challenges. Establishing emission, technology, or some other performance target remains contentious. Also, if the target specifies technologies or forms of energy, instead of focusing directly on the emissions that are causing the environmental or social harm, then it is government making technology or energy choices, which could lead to higher costs than if the market were left to determine the least-cost path to the environmental or social objective.

Conclusion

Most industrialised countries have pursued a greater role for the market in the energy sector over the past couple of decades and, with the collapse of centrally planned economies, this liberalisation trend has become global – influencing the policies of transition economies, developing countries, and international agencies. In industrialised countries, the declining role for government can be primarily attributed to the diminishing view of energy as a public good along with the erosion of natural monopoly conditions in electricity generation.

In developing countries, the focus differs. About two billion people today lack access to electricity and rely on traditional fuels for cooking, using equipment that is highly inefficient and polluting. Providing efficient energy-using technologies and cleaner energy forms is still seen as a public good with wide ranging benefits for sustainable development. Thus governments in developing countries need to find an effective balance of pursuing some of the benefits of liberalisation while also intervening in markets in ways that protect and enhance energy's public good aspects. In general, this involves replacement of some state agencies and public enterprises with private companies and public-private partnerships, better incentives and rate setting for energy services that remain publicly provided, balanced and effective processes for determing and promoting energy efficiency, reduction or elimination of subsidies to conventional energy consumption, and redirection of any remaining subsidies to energy efficiency and to improved access to cleaner forms of energy. This set of policies must be combined with an overall capacity building strategy that improves the prospects for attracting the massive amount of private investment (foreign and domestic) needed to provide adequate and efficient energy services for inhabitants of developing countries. This includes legal, institutional, financial, and regulatory reforms alongside education and training.

Finally, while the public good characteristics of energy can lead to divergent strategies for developing and industrialised countries, the negative environmental and social externalities resulting from energy use are a common concern, and this provides a growing rationale for some form of government intervention in energy markets. Industrialised countries can afford to divert more resources to reducing environmental externalities, but both industrialised and developing countries are challenged by the fact that the externality costs of energy use are often distant in time and place from the point of energy use, which makes policy design extremely difficult. Financial instruments that change energy prices to reflect these damages have better prospects in industrialised economies, with their market tradition, but even in these countries there are significant political constraints to reliance on this approach. For this reason, various forms of regulations – especially market-oriented regulations with flexibility provisions, like emissions caps and technology and market-share requirements – are becoming popular. These can be applied in industrialised and developing economies alike. Furthermore, they can be directed at fuel choices, at the emission level of each fuel, and at the amount of energy consumption needed to provide a given level of energy services.

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3 Towards Sustainable Electricity Policy

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For more than a century, over much of the world, policy and technology have combined to create impressively successful electricity systems. Electric light, electric motors, electronics, and other applications of electricity provide services that have become essential to modern society, including illumination, motive power, communications, and information processing. In industrialised countries, and in many urban areas everywhere, electricity has become the most effective and versatile way to deliver these services; indeed some modern services are possible only with electricity. In these more fortunate parts of the world electricity services have become so reliable and so readily affordable that most people take them for granted.

However, even after a century of expanding electricity development, and despite decades of effort, often substantial, policy has failed to deliver electricity services to some two billion people – one third of humanity. In some rural areas of developing countries, population is expanding faster than electricity systems; electricity is not gaining but losing ground. Sustainable development will require electricity services that are reliable, available, and affordable, not merely for two thirds of humanity but for all of us. Policy to foster sustainable development must include policy to make electricity services available, on a sustainable basis, world-wide.

The circumstances are propitious. For more than a decade, in much of the world, electricity policy has been evolving at breakneck speed. Technical and institutional innovation have overturned many of the traditional guiding premises that shaped electricity systems for a century, inviting fresh thinking. Unfortunately, however, the innovations thus far in evidence have paid insufficient attention to sustainability as a policy objective. Nevertheless the policy ferment now under way offers abundant opportunities for imaginative and constructive new approaches to electricity policy. The aim should be to retain the best of traditional electricity while realising the potential of technical and institutional innovation to foster sustainability.

Traditional electricity systems, replicated all over the world, shared a common technical model and key institutional features. They generated electricity in very large, remotely sited central stations, and delivered it to users as synchronised alternating current, over networks that included long high-voltage transmission lines. A traditional system had a monopoly franchise; in the franchise area anyone who wanted to use electricity from the system had to pay what the relevant government or regulator allowed the system to charge. In all but a few places – notably the United States, Germany, and Japan – the government itself owned and operated the system, and supplied electricity as a 'public service', an explicit responsibility of government. The government charged electricity users – industrial, commercial, agricultural, domestic, urban, or rural – accordingly, setting tariffs for reasons of policy rather than economics. For political reasons, subsidies and cross-subsidies, usually implicit rather than explicit, were an inherent feature of tariff structures.

These traditional arrangements were impressively successful for more than half a century. Despite a variety of problems, they worked well enough to make electricity services ubiquitous and essential in modern industrial society. They did, however, have major drawbacks. The integrated monopoly structure meant that although someone was clearly in charge of the system, planners and managers were not answerable for their mistakes. Captive customers and taxpayers bore all the risks. Investment decisions could be and often were severely ill-judged, in OECD countries, centrally planned economies, and developing countries alike. The social and environmental impact of electricity developments was often deleterious. Some electricity systems became instruments of political patronage, leading to over-staffing and mismanagement. In some centrally planned economies and developing countries the financial burden represented by the electricity system, often aggravated by tariff structures that failed to cover long-run costs, became all but insupportable.

In the late 1980s, governments that favoured 'free markets' began to change the rules. They sold state-owned electricity assets to private investors, abolished the monopoly franchise in favour of competition, redefined networks as frameworks for trading electricity in market-based transactions, and established independent regulators to oversee the process. This process of 'liberalisation' took different forms in different places, and is still very much in flux, both in theory and in practice; it is also controversial. Some governments are pursuing liberalisation wholeheartedly;

others continue to favour tradition. Many are ambivalent and growing more so, as financial and operational difficulties appear to emerge whatever the context. In developing countries especially, where public finances cannot cover the cost of investment to expand systems, liberalisation initially appeared to offer a way to attract necessary foreign investment. But the results have been mixed. Electricity policy is still struggling to understand how best to restructure electricity systems; to introduce competition, electricity trading, and other market mechanisms; to attract private investors and entrepreneurs; and to refocus regulation to advance the economic, social, and environmental objectives of sustainability.

The institutional issues of liberalisation are further complicated by a wave of unparalleled innovation in electricity technology. The onset of liberalisation coincided with the advent of the gas turbine as a generating technology for continuous operation, and of cheap and abundant natural gas to fuel it. Since the early 1990s, gas turbine generation has been the technology of choice for new generating capacity essentially wherever natural gas is available, especially if the host electricity system is in the process of liberalisation. The gas turbine marks a sharp departure from the trend of previous decades, in which a better power station was always a bigger power station farther away. Now, as innovative generating technologies burgeon, a better generator is more likely to be smaller, cleaner, more efficient, and closer to users and their loads.

The rapid success of gas-turbine generation contrasts markedly with the fortunes of the generating technologies previously dominant. Large dams, coal-fired steam-cycle stations, and nuclear power stations all face mounting problems, both financial and environmental, that cast a lengthening shadow over their future role in electricity policy. The corollary technology of high-voltage overhead transmission lines, an essential concomitant of generation remote from loads, now meets implacable opposition wherever a new line is proposed. In a liberalised context, innovative network technologies are emerging; their introduction, however, is hampered by uncertainty about who is to pay for them and how, another major issue now facing electricity policymakers.

The new preference for gas-turbine generation is a manifestation of the new financial structures and relationships arising from liberalisation and competition, creating key issues for policy. A traditional large-scale hydroelectric, coal-fired, or nuclear power station may take at least six years to build, and will then have to operate and sell its output at a satisfactory price for at least another twenty years to produce a return on the investment. In a liberal competitive context, such an investment becomes seriously risky; and the risk is borne not by captive customers but by shareholders and bankers. In contrast, a gas-turbine station, either combined-cycle or cogeneration, can be ordered, erected, and commissioned in perhaps two years, producing a much more rapid and predictable return. Similarly, many new and renewable energy technologies, such as fuel cells, wind, and solar systems, are modular and have short construction times. Moreover, when electricity use grows slowly, adding capacity in modest increments is preferable. Private investors understandably tend to avoid unnecessary risks. The policy and institutional innovations of liberalisation, which change the allocation of risk, thus are interacting with technical innovation to create new options and priorities for the future evolution of electricity systems.

Freed from the stultifying effect of the integrated monopoly, and under the stimulus of liberalisation, much more technical innovation is already emerging: smaller-scale clean and flexible generation; more responsive and versatile networks; end-use technologies offering much higher performance; and information and communication technologies to enable real-time two-way operations and transactions all over the system. As these technologies arrive on a system, its configuration begins to evolve from the traditional centralised structure to one that is much more decentralised, both technically and institutionally. Central planning fades from the picture, and the role of the system changes. Its function becomes to facilitate and fulfil market-based transactions between system participants, including generators and users.

However, the policy implications of such a transition are daunting. It imposes intensifying stress on electricity systems originally built and operated as integrated monopolies. Moreover, some traditional interests inevitably oppose such changes. Governments and regulators must endeavour to reconcile consequent conflicts, to create a stable framework for the transition, to minimise disruption, and to maximise the potential to move towards sustainable electricity services. In the parts of the world where traditional systems are already extensive, the challenge is to devise electricity policy that can keep the lights on reliably, affordably, and sustainably. In China, India, and other developing countries the challenge to policymakers is to cope with growing demand and widen access to electricity services at a breathtaking rate, without intolerable environmental impacts – a daunting dilemma for traditional and innovative electricity alike, and growing rapidly more severe.

Will markets send appropriate signals, early enough to stimulate investment? Will that investment be efficient? From experience thus far, what market design is optimal? How is electricity trading best arranged? In small developing countries, with only one or two generators and limited potential to connect to larger markets, does liberalisation make sense at all? Many developing countries, particularly in Africa, lag behind industrialised countries and emerging economies in liberalising their electricity sectors. This could, however, be beneficial. Developing countries have the opportunity to leapfrog the current phase of liberalisation, by learning the lessons from liberalisation elsewhere and by transforming their electricity systems not merely to provide cheap units of electricity but to provide sustainable electricity services.

Tradition and Its Problems

When Thomas Edison started up his Pearl Street electricity system in lower Manhattan in 1882, he was selling electric light; he charged his customers according to how many incandescent lamps they used. To keep the cost of electric light as low as possible

Edison had to optimise the entire system – the steam engine and generator, the cables and the lamps, all of which he supplied and installed. Soon thereafter, however, came the advent of the electric meter. From that time on, Edison, his competitors, and his successors were selling not electric light but *electricity*, by the metered and measured unit. It was in their interest for a customer to use *less efficient* lamps, motors, and other technologies, because in order to get the same level of service the customer had to use, and pay for, more electricity. This perverse incentive underpinned the development of traditional electricity systems for more than a century.

The traditional electricity system arose primarily because of the economies of scale of the generating technologies most widely used, particularly water turbines and steam turbines. Throughout the twentieth century, electricity policy was dominated by pursuit of the economies of unit scale of generators, and the operating economies made possible by interconnecting different generators into the same network. By the 1960s, the resulting systems were based on very large generating stations, at sites remote from most loads and users, delivering alternating-current electricity over very large networks, including long high-voltage transmission lines.

One key policy issue was how and on what basis to allow networks to use public space. Because of the network, an electricity system came to be considered a 'natural monopoly'. Whether the monopoly was 'natural' or not, a key policy decision, adopted almost universally from the 1920s onwards, was to grant the local electricity system a political monopoly in its franchise area. No one else in the area was permitted to generate electricity for sale. Anyone wanting to buy electricity had to buy it from the monopoly system, and pay whatever the government or its regulator allowed the system to charge. The monopoly franchise in turn allowed the system to order and finance very large installations, including power stations, transmission lines, and other network facilities, because the captive customers of the system bore all the risks. It also allowed the system to invest in substantial amounts of redundant generating and network capacity, to enhance reliability. Captive customers of the monopoly paid for the redundancy, as a form of compulsory insurance.

This traditional model, a vertically integrated monopoly under the close control of government, typified electricity systems all over the world through most of the twentieth century. For much of the time and in many places the arrangements worked remarkably well, bringing down the cost of electricity services until they became part of the fabric of everyday life. Many governments provided electricity as a 'public service', as an explicit responsibility of the government that owned the system. Other governments left electricity systems in private ownership, but established regulators to oversee tariffs and investment, to protect captive customers of the monopoly.

By the 1980s, however, electricity customers and taxpayers in OECD countries and elsewhere were carrying a substantial burden caused by ill-judged investment and poor management. In centrally planned economies, rigid and incompetent bureaucratic management and inadequate engineering and maintenance meant increasingly unsatisfactory performance from electricity systems. In developing countries scarcity of finances, sometimes compounded by incompetent and even corrupt management, led to breakdowns and blackouts. Efforts to extend electricity networks into poor neighbourhoods and rural areas were impeded by shortages of capital for government investment as well as shortages of equipment and skilled labour. A significant proportion of electricity sent out from power stations was simply stolen, not necessarily by the poor but often by those who could well afford to pay. Even when customers paid, electricity tariffs often did not cover costs. This further crippled electricity systems already in grave financial trouble.

Liberalisation, Competition, Markets and Prices

At the end of the 1980s, in Chile and the United Kingdom, governments hostile to state involvement in economic activities and with a strong commitment to free markets broke up their state-owned integrated monopoly electricity systems and sold the assets to private investors. The United Kingdom further announced that the monopoly franchise would be progressively abolished, and that generators and suppliers of electricity would henceforth have to compete with one another to sell their output, under the supervision of a government-appointed regulator. Within two years governments all over the world were pursuing similar processes of liberalisation.

Factors Driving Electricity Reform

A number of factors are driving changes in the electricity systems of most countries in the world. These include the need to improve operating efficiency; a desire to widen customer choice; changes in technology; the need for financing and markets; environmental pressures; and needs specific to individual countries.

Need to Improve Operating Efficiency. Government-owned infrastructure industries historically have played an important role in underpinning economic development. However, as noted, weak performance in finances, investment, and operation, and poor management accountability, have caused governments to embark on fundamental reform and restructuring of electricity systems in a desire to improve investment allocation and operation.

Broadening Customer Choice. Government-owned electricity systems had few incentives to improve efficiencies. Now, however, many governments are aiming to lower costs and prices by commercialising and exposing the industry to greater competition and private ownership. In this new environment, even previously well-regarded companies often show marked gains in efficiency. A commercial and competitive environment exposes the performance of investment planners and managers to market scrutiny. It sharpens incentives to reduce operating costs, and drives wholesale prices to their lowest economic level – although the economic quantification may still not adequately account for subsidies, externalities, other market failures, and similar issues. It exposes investment decisions to their associated risk, and stimulates innovation. It also provides an avenue to access private capital at a time when government budgets are hard-pressed to fund investments. Customers are beginning to demand the right to choose their electricity supplier, further reinforcing the move towards sharper competition, lower prices, and pressures to cut costs and increase efficiencies.

New Technologies. Traditional ways to reduce costs, for example economies of scale in power plant construction by large integrated electricity systems, have largely been exhausted. Innovative technologies, including combined-cycle gas turbines (CCGTs), and distributed generation options such as fuel cells have different scale attributes from those of traditional electricity generation. Instead of economies of unit scale the new technologies tend to have economies of series manufacture, with rapid learning curves. Smaller-scale technologies with different risk profiles allow new, smaller entrants to come into the market. Moreover, new information and communication technologies now enable system control more sophisticated than was previously possible, potentially facilitating short-term electricity trading and including a wide range of participants.

Financing and Markets. Further pressure to reform electricity systems comes from changes in capital markets, sector finance, and various fiscal concerns. Public finance from governments and multilateral lending agencies is inadequate for large infrastructure projects. Governments face growing pressures to reduce their fiscal borrowing requirements and to sell off public assets. At the same time, globalisation of international capital markets has created new financing opportunities, often linked to the participation of private equity partners. The consequent financial difficulties have slowed investments in the large coal-fired and nuclear plants favoured by the large traditional electricity systems.

Environmental Pressures. Concern about global warming and climate change and a general consensus on the need to move towards greater environmental sustainability has reinforced the trend away from traditional electricity generation. The emphasis now is on introducing gas-fired and renewable generation, and on reforming institutions to allow new investors to promote these options.

Needs Specific to Individual Countries. Individual countries also have specific reasons to reform electricity systems. In Chile and the United Kingdom, for example, the governments in power were ideologically strongly committed to privatisation. The U.K. government also wanted to undermine the power of coal mining trade unions; it expected that private generators would purchase imported coal. The rapid emergence of gas-fired generation was only one of many unexpected consequences of liberalisation. In some cases, the reform process may be initiated by a crisis, or perceived crisis, such as the droughts in New Zealand and in Colombia in the early 1990s, which affected hydro generation and caused both governments to consider whether their power sectors could be organised differently. In South Africa, where widening economic ownership and promoting black economic empowerment are key policy objectives, reforming the electricity system and privatising electricity assets could make a major contribution to achieving these objectives. In general, however, the role of liberalisation in delivering electricity services to the two billion people still without them requires profound and careful appraisal, as discussed further below.

Liberalisation and Reform: Key Results

The effect of these various pressures for reforming electricity systems has been to commercialise and corporatise government-owned systems; to change the structure of the industry in ways that increase competition; to create a set of electricity market trading systems; to increase private sector participation; and to change the regulatory system.

Commercialisation and Corporatisation

The first step in reform is often to transform a government-owned system into a commercial corporation, subject to performance contracts and the payment of taxes and dividends. The challenge is to convert a debt-ridden, poorly performing system, reliant on government funding and subsidies, into a corporation able to raise capital on private markets, to meet performance objectives, and to provide fiscal revenue streams. A government can then treat the corporation like any other commercial enterprise whose focus is on maximising shareholder value. Corporatisation involves defining shareholding and share capital; initially the system may still be owned by the state. Initiatives towards commercialising and corporatising help to create a level playing field, in which the cost of capital and what are considered acceptable rates of return on assets are comparable for private operators and the system owned and managed by government. Restructuring and privatisation often follow.

Restructuring to Increase Competition

If new entrants and technologies are to compete effectively, they must be guaranteed open, nondiscriminatory access to the transmission and distribution system. No single generator or supplier should enjoy market power. The simplest way to achieve these objectives is to restructure the industry, and this is often an early step in the reform process. The government 'unbundles' the old vertically integrated monopoly system, separating electricity generation from electricity networks. Generation, transmission, and distribution are then operated as separate, independent entities. The government then unbundles generation horizontally, dividing up existing assets among a number of competing companies, and encourages new generators to join the system. In principle, no generator should be big enough to exert market power; in practice, this may not be easy to achieve, especially since mergers and acquisitions often amalgamate and concentrate generators into oligopolies. Small systems, such as those in most of the developing world, may also be less able to sustain competitive generation.

Any generator may then send its electricity through the transmission and distribution systems to customers. Called *wholesale competition*, this arrangement first emerged in Chile and the United Kingdom and is now being followed by most countries undergoing liberalisation. The process, however, has not always been successful. Governments must take care that one or a few generators do not routinely control the price setting area in the market. In some cases, for example in California, generators have been permitted to retain ownership of their transmission wires. An independent system operator (ISO) then oversees nondiscriminatory access to transmission. In practice, this has often proven costly, expensive, and difficult to regulate.

Governments have sometimes introduced competition in phases, beginning by allowing independent power producers (IPPs), electricity importers, or both to enter the market. An IPP may have to secure future electricity sales through a power purchase agreement (PPA) with the dominant-system company; this arrangement is sometimes called the single-buyer model. Private finance houses mostly insist on these PPAs in order to secure a predictable income stream to service debt. This approach, used in many Southeast Asian as well as other developing countries, involves a number of compromises. It denies full wholesale competition, giving the traditional-system company a dominant market position because it controls most of the generating capacity and the transmission system. Moreover, it may saddle the government and the traditional-system company with costly PPAs that become uncompetitive; a PPA might dictate a fixed price over a long period, whereas introducing full competition might make electricity prices fall.

A growing consensus is emerging in favour of introducing full wholesale competition from the beginning. This entails separating generation from transmission, while guaranteeing generators non-discriminatory access to the network to transmit electricity to customers; and separating generation into a number of competing companies, none large enough to exert market power.

At a later stage of liberalisation, the operation and ownership of the distribution wires becomes an activity separate from the supply of electricity to customers. A number of suppliers compete to sell electricity, and customers can choose their suppliers – so-called *retail competition*. Large customers are often allowed to choose their suppliers when wholesale competition is first introduced; smaller consumers get the opportunity at a later stage. Suppliers buy their electricity from the wholesale market, and pay the transmission and distribution companies a *regulated price* to transport their electricity to customers. Customers may thus see their electricity bill split into an *energy cost*, representing the price of electricity bought from a generator, and a *transport cost*, representing the charge for using the wires. Customers may also elect to purchase their electricity directly from generators. The United Kingdom, Norway, New Zealand, Australia, and many other countries have moved to retail competition, beginning by allowing large customers to choose suppliers, and then gradually extending competition to all electricity customers. Retail competition offers suppliers the opportunity to compete on the sale not merely of anonymous units of electricity at a customer's meter, but of electricity services, including services on the customer's side of the meter, an option that may become increasingly important, as discussed below. See Box 3-1 for a discussion of the changing market electricity structure in Nordic countries.

In developing countries, retail competition could result in electricity prices that the poor cannot afford to pay. The implicit cross-subsidies that help keep prices down for poorer consumers in a traditional system would have to be made explicit. To address this issue, policies on cross-subsidies for social purposes would have to be much more carefully designed and implemented. For example, subsidies could be targeted towards the capital cost of the connection, rather than the operating or energy costs. The licensing system could include incentives for distributors to make new connections; and poor households could be exempt from some proportion of the wires charges.

Box 3-1
The Nordic Electricity Market

During the last decade, a new electricity market structure has been created in the Nordic countries. The Nordic region, which includes Norway, Sweden, Finland and Denmark, has 24 million inhabitants and nearly 400 terawatt hour (TWh) per year in electricity demand.

The new market was built on a long tradition of trading power, both within each country and among countries, which resulted in cost-effective use of the production resources in the Nordic countries. The driving force behind the trade was the variation in production structure among the various power companies. Production in Norway, North Sweden, and North Finland is almost entirely hydropower. Production in the rest of the Nordic area is almost entirely nuclear power and thermal power.

The principal goal for the changes during the last decade was to include not only the producers but also the users and suppliers in a competitive market. New legislation stating that all end-users are free to choose their supplier has been established in each country. The main transmission networks were separated from the biggest producers and organised as independent national grid companies with the role as Transmission and System Operator (TSO). If producers or suppliers had regional or local networks they had to organise them in separate units.

These changes have enabled the suppliers to sell electricity to customers outside their ordinary area and even to other countries. The changes have also resulted in new entrants and new companies for new functions in the electricity market (e.g., brokers and portfolio administrators). However, they have also resulted in consolidation through mergers and take-overs.

One important development is the creation of Nord Pool, the Nordic power exchange. Nord Pool started its operations in 1993 in Norway. In 1996, it was widened to include Norway and Sweden, with Finland following in 1998 and Denmark in 2000. Nord Pool organises a physical day-ahead market and a financial market with clearing services. The clearing services are also available for the bilateral financial market.

In the *physical day-ahead market*, trade in physical hourly contracts for delivery the following day is conducted through an auction procedure. Bids from over 200 participants are delivered before 12 a.m. In a bid, a participant states for every hour for the following day how much he wants to buy or sell at different prices. Nord Pool aggregates the bids for every hour into one demand curve and one supply curve. The intersection point becomes the Nordic system price for that hour. If that price results in power flows exceeding the capacities between the different areas, separate area prices are calculated. After the calculation, participants receive a contract showing how much they buy from or sell to Nord Pool for each hour and price area.

After the physical day-ahead market, the participants report to the TSOs their planned hourly balance (production, purchase, consumption, and sale) in various geographical areas. If deviations occur, participants can adjust their balance through trade or physical measures until the hour before delivery. Real-time imbalances between production and consumption are handled by the TSOs in their regulating markets. Active bidders in the regulating markets are producers and big consumers who are able to respond quickly to imbalances by adjusting their production or consumption. The TSOs also have access to reserves for frequency regulation which they have procured in advance. Afterwards, participants' imbalances are settled by the TSOs by applying the regulating market price for each hourly imbalance.

The participants can mitigate the consequences of volatility in the physical market through hedging or risk management in Nord Pool's *financial market*. Financial contracts are traded for the next weeks, seasons, and years (up to four years ahead). Options can also be traded. The participants place their bids in an electronic system. A trade is done when bid and ask prices are equal. After the trade, Nord Pool is the counter party to both parties. If two participants have traded bilaterally, they can decide to clear their contracts at Nord Pool, meaning that Nord Pool becomes the counter party to both parties. The financial contracts do not result in physical delivery. Instead, they result in a financial settlement during the delivery period. The reference price for the settlement is the system price in the physical day-ahead market.

This combination of physical and financial markets enables the participants to buy or sell in a very liquid physical market and to make financial hedges according to their risk management strategies in a very liquid financial market. It also enables trading companies without physical assets to take part in the financial market and increase the liquidity in that market. The participants in Nord Pool's markets are obliged by a strict information duty concerning their plants. The purpose is to ensure a level playing field among the participants and trust and transparency in the price formation. Nord Pool also has a market surveillance department.

Trade activity through Nord Pool has been expanding rapidly. During 2001, the trade volume was 111 TWh in the physical day-ahead market, 910 TWh in the financial market, and 1,748 TWh in cleared bilateral financial contracts. This means that 29 percent of Nordic electricity demand was bought through Nord Pool's physical market. The total financial market (exchange-traded contracts and cleared bilateral contracts) was more than six times bigger than total Nordic electricity demand. A financial contract is normally traded many times before delivery. The total value of traded and cleared contracts was NOK 412 billion (US$46 billion). More information about the markets is available at www.nordpool.com.

Some of the main issues for the further development of the Nordic electricity market are increased demand flexibility, handling of market concentration, and the development of 'green certificates'. Increased demand flexibility is important especially for the handling of capacity peaks and as a complement to new production investments. Market concentration necessitates an even more integrated Nordic market and intensified market surveillance. Introduction of 'green certificates' will combine a competitive electricity market with market-based incentives for electricity production from renewable sources.

Björn Hagman

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Electricity Trading

A key element necessary for competition is the creation of an electricity market or set of trading mechanisms and instruments. Thus far, two broad market models describe the way in which sellers and buyers of electricity interact.

The *power pool model* has been widely implemented, initially in England and Wales and now in Australia and elsewhere. In this model, generators bid their electricity into a pool – that is, a block of electric power at a particular price for a particular period, usually an hour or half hour a day ahead. The bids are stacked from the lowest to the highest. On the basis of a demand forecast, and a succession of bids from the lowest price upward, the pool operator prepares a day-ahead commitment and dispatch schedule. Generators are dispatched to meet demand; generators whose price is too high are not dispatched. Purchasers buy their electricity from the pool at a price that is based on the bid of the most expensive plant dispatched, the so-called 'system marginal price', plus any so-called 'capacity payments' such as fixed charges for connections. The system operator handles constraints, largely by adjusting the dispatch schedule, and procures ancillary services such as reactive power and voltage regulation. The operator balances the system instant by instant by means of a separate so-called 'balancing market', with separate price schedules for short-term increases or decreases in generation output or electricity use. The costs of system operation and balancing are added to the pool price as an uplift payment. All generators and users have to purchase or sell electricity through the pool, although they may hedge their risks with financial contracts for differences. In this model, electricity customers have little incentive or opportunity to balance the system by reducing load rather than increasing generation.

As more experience with competitive electricity markets accumulates, a *multiple electricity trading market model* is evolving, in which power is not all traded through a single pool. A market develops for long- or medium-term bilateral contracts between generators and suppliers or customers, or both. Transactions between market participants no longer centre on a single system marginal price. Instead participants bid both supply and demand, and pay the prices bid or agreed. Participants hedge market risk by trading in futures or forward contracts. A power pool becomes a day-ahead market, usually establishing the reference price. Because electricity cannot be stored, and supply must match demand in real time, a balancing market becomes critical. All market participants who are out of balance from their contracted positions will be exposed to the price in the balancing market. These various market platforms have rules and settlement procedures that are clearly delineated. Essential elements of this model are that buyers and sellers are free to choose their trading platform or platforms and that it strengthens participation from the customer´s side of the meter; reducing load becomes a valid balancing mechanism, compensated accordingly. It also creates explicit markets for balancing functions that an integrated electricity system would provide implicitly.

The general trend towards competition and the creation of electricity markets may not be beneficial in all contexts. South Africa is discovering, for example, that prices of electricity traded in a market may turn out to be higher than those from a regulated monopoly. This might be true in situations where the cost of new supply is higher than historical investments, for example amortised coal plants without environmental controls, and where the regulatory system is based on low returns on historical assets. Regulated prices tend to be based on *average* costs. South Africa had a history of significant over-investment; much of the debt from past investments was subsequently amortised, thus making average costs low now. A competitive market will deliver a price that reflects the marginal cost of *new* investment – which in South Africa's case is likely to be higher than current average costs. In a competitive market that reflects long-run marginal costs, the incumbent generator would earn windfall and excessive profits. According to market proponents, in the long run, a competitive market will lead to improved allocation and operational efficiencies that will drive prices below those from a regulated monopoly.

Some analysts have compared new electricity markets to commodity markets. However, in crucial respects, electricity is different. It cannot be stockpiled like commodities such as fuels or minerals, and held back from a market until the price is right; indeed it cannot be stored at all, as electricity, in the quantities in which it is used. Thus if markets are to deal in electricity as a commodity priced by the unit, they have to accommodate real-time balancing of supply and demand. One consequence is that electricity trading systems must involve highly complex, sophisticated, and expensive information and communication technology. The computer system that governed electricity trading in England and Wales in the first decade of liberalisation was more complex than that for the London stock exchange. This complexity is reason enough to suggest that developing countries consider carefully the market structure and electricity trading arrangements that might be appropriate for their contexts and constrained resources.

Wholesale electricity trading deals primarily with units of electricity, measured, priced, traded, and sold, with financial contracts typical of commodity transactions. However, as the retail electricity market selling to final users emerges, it may be very different. One question in particular needs to be addressed: is this competitive retail or supply market to be merely a commodity market, in anonymous units of electricity delivered to a user's meter? Or can suppliers offer competitive electricity *services*? This issue is discussed later in the chapter.

Increased Private Sector Participation

The electricity system can be restructured and competition introduced while keeping most of it in government ownership and without privatising. This is the case in Norway and was the initial phase in the reform process in New Zealand and in the Netherlands. Other countries such as the United Kingdom, Chile, and Argentina restructured and privatised simultaneously. The private sector can enter the electricity system, either by investing in new independent power producers (IPPs) or by purchasing government-owned assets when they are privatised. Governments can privatise by inviting strategic equity partners, by targeted equity sales, by auctioning assets, or by an initial public offering (IPO).

Some argue that the full benefits of competition can only be realised when the industry's competitive elements – generation and supply – are fully privatised. The profit motive and exposure to investment risk are considered added incentives for cost reduction.

Modernising the Regulatory Framework

Liberalising electricity is often assumed to be associated with deregulation. The contrary is true. As government-owned systems have been commercialised and corporatised, taking them further from direct government management and control, governments have had to establish a clear regulatory framework both to protect consumers and to provide incentives for private investors and managers to improve efficiencies and drive down costs. As the electricity system has been restructured to introduce competition, the parts that are competitive and can be overseen by existing authorities must be distinguished from the parts that may be considered 'natural monopolies' and must be regulated accordingly.

Generation and retail supply – that is, direct transactions with final users – lend themselves to competition. System services such as metering, market operation, settlements, etc., which can be put out periodically to competitive tender, or where parallel trading mechanisms develop, may also be subject to competition. On the other hand, networks for transmission and distribution have historically been considered natural monopolies. Although the point is disputable and is increasingly disputed, especially by advocates of private wires, for the moment liberalisation tends to leave networks as monopolies, to be regulated as such.

Regulation has moved away from the old 'command and control' approach, in which governments set and approved electricity prices. Instead regulation today may be based on cost of service, for example, rate of return, common in the United States. Alternatively, it may use mechanisms designed to affect conduct or offer incentives, such as price capping with an efficiency factor, for instance inflation minus X in the United Kingdom; revenue capping in Norway; or time-limited franchises. Within these broad regulatory methodologies, the practice of regulation still involves some difficult choices, for example, whether to adopt nodal pricing for networks, or how to allocate access costs fairly among generators, networks, and users. In general, electricity regulators are also responsible for technical regulation, including issues of quality of supply and safety.

In the past, electricity regulators tended to license not only transmission and distribution companies but also all electricity generators and retail suppliers. Regulation and oversight of generators and suppliers now tend to come under the jurisdiction of general competition authorities, although electricity regulators still often monitor the electricity market for signs of market power and market abuse. In some instances, regulators have played an active role in forcing structural change in the industry. For example, the Office of Electricity Regulation in the United Kingdom forced divestiture of generation assets to reduce market power.

No consensus exists yet either on what the ideal structure of an electricity market is or on how to organise electricity trade. The electricity markets of California, England and Wales, Norway, Australia, Argentina, and Chile are all very different. An area of persistent concern is whether electricity markets can send adequate and timely signals for new investment. If generating capacity is sufficient, highly competitive market prices will tend towards the short-term marginal cost – which will not attract or support new investment. As supply shortages occur, competitive prices will tend towards the long-run marginal cost of new investment. The risk is therefore that market prices will be cyclical, and that liberalised markets could result in periods of scarce supply. On the other hand, market prices may not themselves be uniform, or indicate the whole story. For instance so-called ‘green electricity’, generated from renewable energy without polluting emissions or greenhouse gases, is beginning to gain market share because of its environmental desirability, and may even attract a premium price. Some governments, including several in western Europe, are establishing ‘green certificates’ to characterise electricity meeting suitable criteria, as a stimulus to investment in innovative clean generation. Governments can then require generators and suppliers to hold at least a minimum quantity of such certificates, or be penalised.

Each developing country has to address the particular problems presented by its own traditional electricity system, and to respond to those specific drivers for change – not to those that may arise in very different contexts. Developing countries have to consider carefully the lessons from liberalisation of electricity systems elsewhere, and select models that allow them to meet their goals for economic, social, and environmental policy on a sustainable basis. Box 3-2, describing the California experience in 2000–01, shows that it is not necessarily easy to modernise or restructure electricity systems.

Box 3-2
Lessons from the California Electricity Crisis

Beginning in the summer of 2000, California suffered an electricity crisis that has caused many to doubt the wisdom of efforts to introduce customer choice into electric power markets or even of major restructuring of electricity systems. Other U.S. states and other countries have experienced problems of supply availability and of extreme price volatility in electric power markets, but in California the problems were particularly severe, widespread, and long lasting.

The crisis consisted of frequent blackouts, extraordinary volatility in wholesale prices, and the bankruptcy of one large California private utility as well as the near bankruptcy of another. The crisis also resulted in the abandonment – at least for now – of California's experiment with customer choice in retail electric power markets. It has made other U.S. jurisdictions (although not all) hesitant to move forward with similar experiments.

At the peak of the crisis, California wholesale electricity prices increased from the 2–3 cent per kilowatt hour that had prevailed for most of 1998–99 to as much as the 37 cents per kilowatt hour in December 2000, before falling back into the 4–5 cent range in late 2001. Many owners of California generating stations reported extraordinary profits for the period during which the high prices prevailed. However, the two largest distribution utilities were prevented by the price-cap arrangements that they had negotiated during the passage of California's restructuring law from passing these high prices on to their customers. As their credit quality deteriorated, power suppliers declined to sell to these utilities, and the state became a buyer in their place. By contrast, restructured utilities elsewhere in the United States generally negotiated successfully for a right to recover such costs after their price-cap period expired. In some countries that introduced retail competition while privatising government-owned utilities, the government absorbed the transition costs. Investigations and lawsuits regarding the California events are under way, and the role of market power and the possibility of illegal market manipulation by some power generators remains under investigation at the state and federal levels.

Nonetheless, it is already clear that the California energy crisis had many causes, including failures in the design of the state's restructuring plan, prohibitions on distribution utilities entering into long-term contracts, excessive concentration of market power, lack of rainfall (and therefore hydroelectricity) in the Pacific Northwest, and a shortage of natural gas resulting in part from the extended loss of a major pipeline. Some argue that the manmade among these flaws can be corrected and that competitive retail electric markets can then move forward.[1] Others maintain that unique aspects of electricity (e.g., that it cannot be stored and the public's low tolerance for price volatility) make it unsuited to reliance on competition at the retail level.[2]

From the standpoint of sustainability, the California crisis teaches a number of important lessons. First, California adopted a market design that did not value efficiency and load management appropriately. The dismantling of the regulated monopoly structure in California in the 1990s was accompanied by a significant drop in spending on energy efficiency, which cost California an estimated 1100 megawatts in energy savings by 2000. This drop occurred because utilities, with state approval, reduced spending on energy efficiency in anticipation of retail competition, thereby departing from the historic California policy of taking into account both the market barriers to and the societal benefits from energy efficiency.

Second, the restructured California market did not permit energy efficiency and load management to participate on equal terms with new supplies. This flawed market design left the California Independent System Operator paying ten times more to buy power than customers would have charged to save the same amount. The market mechanisms and metering devices necessary to allow the demand side of the market to respond to price signals are still being implemented.

Third, in anticipation of lowered prices from conventional sources in the new 'market', California utilities in 1995 persuaded the Federal Energy Regulatory Commission to override a state requirement that they purchase 1400 megawatts from renewable sources over the next few years. These renewable resources, together with the energy efficiency noted above, would have substantially mitigated the crisis.

Fourth, California citizens responded dramatically and successfully to the crisis by reducing their consumption by some 6 percent in the first half of 2001, showing the contribution that energy efficiency can make in a crisis even when few advance planning and price incentives have been developed. The measures taken included intensive public information, rate incentives, and incentives for more efficient appliances, as well as an extensive conservation program by the state government itself. By underestimating the extent of the efficiency response and signing long-term contracts to ward off an extended crisis, California is now committed to paying apparently excessive prices for power that customers turn out not really to need, at least at the price they must pay for it.

Fifth, California has learned the need for continued state involvement in power supply management in order to assure that values that the short-term market tends to ignore – such as reliability, price predictability, environmental impact, and the furtherance of renewable energy – are reflected in power procurement decisions.

Finally, California teaches again the need to avoid learning incorrect but enthusiastically propounded lessons from any crisis. Each of the following statements, widely propounded during and after the crisis, has been shown to be incorrect.

- California has not built any power plants in the 1990s. *California actually added more than 4000 megawatts of new capacity in the 1990s, most of it in the form of small nonutility units. The shortages were in any case not caused by an insufficient amount of generation. Some of the shortages occurred at times when demand was as much as 15,000 MW (33 percent) below the amount of generating capacity available to the California Independent System Operator, far below demand levels that had been met comfortably in previous years.*
- Rapid demand increases caused in large part by the Internet contributed to the crisis. *Actually, California energy use grew at 1 percent per year, less than half of the national average growth rate throughout the 1990s. Internet usage in all its forms is a small fraction of total demand in California and elsewhere.*
- California's rigorous environmental standards discouraged the building of new power plants. *No responsible developer has claimed that California laws discouraged new plants, and several new plants were sited and built rapidly in the eighteen months prior to the crisis.*
- The California state government brought on the crisis by refusing to allow the utilities to recover the increasing costs of the power that they needed to acquire.

In negotiating the California restructuring bargain, the California utilities agreed to a retail price freeze from 1996 through 2002 in return for an assured chance to recover the full cost of their past nuclear and other expensive investments during the transition to competition. In essence, they entered into a long-term contract with the state to sell electricity at a fixed price until 2002 (unless the above-market investments were recovered sooner) in return for other considerations. In hindsight, the state might have been well-advised to relax the bargain and permit rate increases sooner (perhaps with a commitment to repay customers once the crisis had passed), but such increases would have contradicted the assurances of stable rates that the utilities had given during the highly public referendum campaign that sealed the California restructuring bargain in 1997.

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[1] See, for example, William W. Hogan, California Market Design Breakthrough, at http://www.ksg.harvard.edu/hepg/Standard_Mkt_dsgn/Hogan%20Cal_Mkt_Design_01-14-2002.pdf.
[2] See, for example, Richard Rosen et al., Can Electric Restructuring Meet the Challenges It Has Created (Tellus Institute, 2001).

Technological Innovation

Electricity as an energy carrier depends inherently on technology. Only with technology can electricity be produced, delivered, and used. Electricity is not a fuel; it is a physical phenomenon happening simultaneously and almost instantaneously throughout an entire interconnected technological system of generators, network, and loads. A policy framework appropriate to fuels such as wood, coal, oil, or even natural gas, which can be produced, stored, priced, and sold in batches, as commodities, is much less appropriate for electricity, whose technological attributes are fundamentally different.

A fuel is produced at a particular location. If it is to be used anywhere else it must be physically carried there, either in batches by human individual, pack animal, train, truck, or ship, or continuously by pipeline. Electricity, by contrast, can be generated anywhere, at a cost. As noted earlier, the entire technological configuration of traditional electricity – central-station generation, alternating current, and long-distance high-voltage transmission – arose because for decades, with the technology available, that was the cheapest way to produce and deliver electricity to operate loads such as lights and motors. However, even the criterion of 'cheapest' depended critically on the policy framework, particularly the monopoly franchise. By allocating the risk of long-term investment to captive customers, the monopoly franchise kept down the cost of capital, a substantial proportion of the cost of a unit of electricity delivered at the user´s meter. In this and other ways the interaction between technologies and finances, with the consequent policy implications, played a determining role in the expansion of electricity throughout most of the past century.

Within little more than a decade, however, the interaction of liberalisation and technical innovation has profoundly altered these circumstances; and the innovation of electricity technologies is accelerating. In some ways this is unexpected. During the heyday of traditional electricity, not only equipment manufacturers but the vertically integrated monopoly organisations themselves pursued major programmes of research and technology development (RTD). Government-funded research agencies did likewise, particularly on technologies for nuclear electricity. With the advent of liberalisation, RTD become one of the first activities to be cut back, as the newly private companies strove to reduce costs, and governments withdrew RTD funding. At the time some commentators decried the RTD cutbacks as a negative consequence of liberalisation. Others, however, pointed out that a great deal – arguably the majority – of expenditure on RTD for electricity technologies by monopoly electricity organisations and government agencies had been essentially wasted, on technologies that never achieved commercial success. The risks of RTD, like those of other expenditures, had been borne by captive customers and taxpayers. Those who planned RTD programmes did not have to answer for misjudgements or mistakes; programmes clearly unsuccessful continued to run because those in charge were not compelled to cancel them, and thus admit failure.

The key issue for RTD as an aspect of electricity policy therefore is who is to do the RTD, why, and on what basis, especially financial. Some key innovative technologies have benefited from the support of government, particularly through military RTD. The gas turbine, to take but one conspicuous example, emerged from the military jet aircraft engine. Nevertheless, since the beginning of the 1990s most RTD on electricity technologies has been conducted and financed, not by governments nor by electricity companies, but by engineering companies that expect to market the technologies and earn a commercial return on them. The engineering companies involved include some completely outside the traditional electricity sector, for example car manufacturers investing in technologies such as fuel cells for vehicles, that may also be important for electricity systems. Some argue that this is the more appropriate way to pursue RTD for electricity, imposing market disciplines to ensure the most effective allocation of funds, effort, and risk.

A further consideration, however, also affects policy. Many of the most promising innovative technologies have to compete with traditional so-called ‘legacy’ technologies, which have already benefited from years and indeed decades of direct and indirect government support, and may well continue to do so. Policy on technical innovation must therefore establish the kind and degree of support that government should offer to innovative electricity technologies, even in a liberalised market context. This becomes yet more pressing when innovative but immature technologies appear likely to offer major public benefits, social and environmental, and to further the aims of sustainable development. Policy promoting RTD of innovative technologies will be a key ingredient of effective electricity policy for sustainable development. The most important aspect may be to support deployment and demonstration, at the initial stage of commercialisation, and to ensure that the existing system can accept, accommodate, and integrate the innovative technologies. An interesting example is Brazil, which imposes a systems benefit charge and then allows electricity industry players to claim back RTD expenditure. The federal authority also sets RTD priorities and allocates funds.

Even without a coherent or fully realised policy on RTD, innovation is racing ahead. Generating technologies are perhaps farthest advanced, in the sense of diverging the most from traditional types. As already mentioned, the most successful new generating technology to date is the gas turbine, particularly in combination with a steam turbine in the form of so-called ‘combined cycles’ (CC). Many CC stations are similar in size and operating characteristics to traditional generating stations, and fit readily into traditional networks, both technically and institutionally. The gas turbine also lends itself well to cogeneration, producing from the same fuel both electricity and useful heat in the form of steam or hot water. A further option, potentially important especially in low-latitude developing countries, is to add an absorption chiller to the installation, to produce cooling as well, for refrigeration and air conditioning. However, a gas turbine unit in cogeneration mode, like any other cogeneration unit, operates according to the local requirements for heat or cooling. Its electricity output is effectively a byproduct, and cannot therefore be centrally dispatched. For traditional systems that assume all generation is dispatched, cogeneration is thus a departure from traditional norms that is already causing problems for policy.

The trend in gas turbine innovation is revealing. Much of the most promising recent work is not on larger gas turbines but on smaller ones, down to tens of kilowatts of electricity output – so-called mini-turbines and micro-turbines. These small machines offer a cleaner, less noisy, and more environmentally acceptable alternative to traditional diesel generation, not only in its traditional role as emergency on-site backup generation but also for continuous operation. Large gas turbines, with outputs of over 200 megawatts, present no difficulties for traditional networks. Micro-turbines, on the other hand, could presage a dramatic change in the role and function of networks – not only electricity networks but also gas networks. So could the rapidly expanding array of other small-scale generating technologies, including Stirling engines and fuel cells down to residential size. These technologies differ so radically from traditional generating technologies that their emergence presents a major challenge to policy, and to the future structure and function of the electricity system.

The mismatch between small, decentralised generators and traditional networks is already a major impediment to the expansion of innovative so-called ‘distributed’ generation, causing intense controversy in many places. It is a key issue for the future of technologies that use renewable energy to generate electricity, including wind energy, biomass energy, and photovoltaics. Even wind generation, to date the most successful renewable energy technology, cannot be dispatched; the output of an individual turbine generator depends on the wind. The traditional policy framework for network operation considers this a problem, compared to generation based on large dams, coal, or nuclear power, all of which can be dispatched, at least to some degree. Network protocols influenced by this traditional criterion penalise small-scale generation by treating each generator, however small, as though it were equivalent to a traditional generator with output in hundreds of megawatts. The resulting requirements for backup and standby generation, not to mention disproportionately costly network connections, and concomitant financial penalties for non-dispatchability, are making otherwise attractive decentralised generation too expensive to consider.

Advocates of decentralised generation argue that as far as the system is concerned a one-megawatt generator is technically essentially equivalent to a one-megawatt industrial motor – connecting the one is much the same as disconnecting the other, and should be treated the same way. An interconnected system whose total generation and load are measured in gigawatts or tens of gigawatts can cope easily with a one-megawatt change in either direction. Stability problems arise not from small-scale generation but from the possibility of losing a single large traditional unit, sending a step change transient of perhaps 500 megawatts across the network and tripping protective devices for hundreds of kilometres. A becalmed wind turbine, by comparison, is trivial, especially on a system that might eventually have many thousands of such small generators all in operation simultaneously.

In developing countries, extending the electricity network into remote rural areas, where a substantial proportion of the population resides, is simply unaffordable. Traditional off-grid technologies such as diesel generators, and newer technologies such as solar-home systems based on photovoltaics, remain expensive. In many cases, nevertheless, they may be competitive with rural electrification by means of the network. Where electricity services are highly valued, for example vaccine refrigeration, these smaller-scale technologies are making significant inroads. Innovative entrepreneurial and business-based solutions are also emerging, for example the spontaneous, non-regulated mini-grids powered by diesel generators in rural Cambodia, or the competitive concessions for rural electrification in Argentina. However, without targeted subsidies, many of these technologies are simply beyond the reach of the majority in rural areas in developing countries. If distributed generation technologies and service delivery systems are to make a real contribution to sustainable development, they still have to make a significant breakthrough in reducing costs and expanding availability.

A parallel experience, however, may be encouraging: mobile telephony has expanded rapidly in developing countries, even in rural areas. Technical innovation has lowered costs, and financial innovation in pre-payment systems has brought telephone communication to millions where it did not previously exist. Similarly imaginative solutions, bypassing tradition to 'leapfrog' directly to the next stage of technology and policy, could transform electricity arrangements in developing countries. The report of the Renewable Energy Task Force of the Group of Eight (G-8) leading industrial countries released in July 2001 declares that these technologies must first be developed and demonstrated in OECD countries, to prove that they are effective and economic. But electricity systems in OECD countries may have a much more intractable burden of 'legacy' technologies and institutions. Opportunities clearly arise for cooperation between OECD and developing countries, to demonstrate renewable generating technologies on systems in developing countries that can more readily innovate.

After a slightly slower start, technical innovation for networks has also begun to take off. Power electronics capable of handling and switching transmission-level currents and voltages are improving at a remarkable rate. So-called 'flexible alternating current transmission system' or FACTS technologies offer the potential to increase substantially both the capacity and the flexibility of high-voltage AC networks. High-voltage direct current (HVDC) technology adds another promising option, eliminating both the phase problems of very long AC lines and the transients that can travel along them. HVDC interconnections, with compact power electronics to convert between DC and AC, have become an important factor in linking up systems that may be difficult or impossible to synchronise, especially internationally. Some developing countries are also pioneering lower-cost distribution technologies such as Single Wire Earth Return (SWER), and adopting more efficient backbone sizing based on realistic assumptions about diversity, maximum demand, and load growth.

The key policy problem facing these and other innovative network technologies is not primarily technical. In a liberalised framework, the questions to be answered are clear and unambiguous: who is to finance the requisite investment, and how will it be recouped? For innovative generation, the decisions and the investment may be made by entrepreneurs who propose to earn revenue by selling the output of the generation; by electricity users who want to have control over the cost, quality, and reliability of their own generation; or by energy service companies contracting to deliver generation and its services to clients. For innovative networks, however, the status of the network, its ownership, operation, maintenance, expansion, interconnection, and use are all subject to an assortment of regulation and constraints that are themselves evolving, rapidly and often incoherently. Some commentators and entrepreneurs are now looking to the advent of so-called 'private wires', outside the traditional network monopoly, to carry electricity from private generation direct to users, under bilateral contracts and other arrangements. Once again, however, the policy implications are significant. If, for example, private wires came to carry all the most lucrative electricity business in a locality, who would provide the connections and the electricity services to less favoured users such as poor neighbourhoods and low-density rural areas? The question is not unanswerable, but policy must address it at an early stage; even in OECD countries it could become a serious issue.

One key aspect of technical innovation, sometimes overlooked or taken for granted in electricity policy, is innovation in end-use devices. Even for the main traditional electricity services of illumination and motive power, recent technical developments have been substantial. They include, for instance, compact fluorescent lamps whose high performance and durability make them investments, not running costs like traditional incandescent lamps; and variable-speed motor drives that enhance the performance of electric motors over their entire operating range. Such innovations, delivering better services while using less electricity, are often characterised as 'energy efficient'; but even when 'efficiency' is in practice difficult to quantify, the improved performance is clearly beneficial, both economically and environmentally.

However, a further category of technical innovation represents a yet more fundamental issue for electricity policy. An increasing proportion of the loads attached to electricity systems in OECD countries and elsewhere, such as computers and other electronics, require electricity of very high reliability and power quality. In some applications of computers, for example data processing for financial services, a very brief outage can cost millions of dollars. An interruption of less than a single AC cycle can have serious consequences for sensitive chips that may control a delicate industrial process or contain the value of a company. In the United States, the criterion has come to be called 'six nines': that is, at least 99.9999 percent reliability. Even on a traditional vertically integrated monopoly system with ample redundancy, reliability so demandingly high cannot be guaranteed. On a liberalised system operated in a competitive market mode, the redundancy of both generation and network capacity is reduced; the system is operated closer to its technical limits, and reliability may suffer accordingly.

Some commentators argue that this demand for high reliability and power quality, and the corollary demand that the user have control over it, may prove to be a potent driving force towards on-site generation, local electricity systems, so-called 'mini-grids', and what has been called the 'virtual utility' – a decentralised, heavily instrumented, multiply interconnected network of generators and loads of broadly similar sizes, essentially self-stabilising and mostly self-contained. As and when they occur, such developments will mean a substantial and continuing reconfiguration of the electricity system, its function, its operating regime, and the relationships between system participants and operators. The technical innovation involved, although complex, will be simple compared to the institutional and policy innovation it will entail – especially if the transition is to take place while keeping the lights on.

If we were starting now to electrify society, with the innovative technologies already or soon to be available, electricity systems would look very different. However, in OECD countries and in many parts of transition and developing countries we must approach the transition from where we are, with electricity systems already in place; we cannot start from somewhere else. On the other hand, for some two billion people, we are indeed only starting now to electrify society. We have, so to speak, an almost clean slate. We can strive to get it right from the outset, to move towards sustainable electricity services. We should seize the opportunity.

Improving Energy Services

For much of the twentieth century, traditional electricity systems were devoted to promoting the use of electricity, building the electrical load and expanding the system to meet it. Using more electricity was regarded as a measure of economic success; electricity policy was designed and implemented accordingly. As electric lighting and electric motors became commonplace, a succession of other applications of electricity were devised and marketed, to deliver other energy services. For some of these services – such as the provision of low-temperature heat for comfort, hot water, and cooking – electricity was not obviously necessary, or even especially advantageous. But system revenues came from selling electricity; the system did not care how it was used, so long as it was used. If electricity customers used inefficient equipment, so much the better. The system actually benefited, because customers had to use, and pay for, more units of electricity to obtain the same level of service. Expanding the system was a sign of economic vigour.

By the 1970s, however, in many places this approach was running into trouble. Both the cost of additional generating and network capacity, and the time required to bring it into operation, were increasing to unacceptable levels. Captive customers of monopolies who had been complaisant while electricity bills were going down grew restive when the bills began to rise. Moreover the public that had once welcomed new electricity facilities as symbols of progress was now likely to mount stubborn and vociferous opposition to new generating stations and transmission lines. The environmental impacts of electricity systems – visual impact, gaseous emissions, waste disposal, and other negative corollaries – became a long-running political and social issue. The oil shocks of 1973 and 1979, and the economic downturns that resulted, made nonsense of forecasts of future use of fuels and electricity. Over-expansion of electricity systems became endemic throughout most OECD countries. By the early 1980s the gap between system capacity and actual electricity use would have caused a financial crisis if bankers rather than captive customers had paid for the superfluous investments.

By the late 1970s, to address the mounting problems of expanding system capacity, some commentators were advocating a startling policy innovation called 'least-cost planning' (LCP). Instead of assuming that the load on the system was independent of system planning, and that the rest of the system had to expand to meet this independent load, LCP undertook to compare alternatives. Which was less costly – to invest in new generation and networks to meet increasing load, or conversely to invest in improved end-use technologies to reduce requirements for increased generation and networks? In many instances investing in improved end-use technologies was obviously quicker, easier, and less expensive. If the electricity system were regarded as an integral whole, such end-use investment would be the sensible and appropriate way to deliver more services with lower cost, and usually also with lower environmental impact.

The entire system, including all loads connected at any given instant, had to operate as an integral whole, continuously in real time. Unfortunately, however, the system was far from an integral whole in one critical respect: the end-use technologies – the loads – did not belong to the owners of the power stations and networks. The different owners all had to comply with stringent operating protocols, to keep the whole system stable. They did so on the basis of agreed financial and business relationships, as laid down by government or its regulator. But the owners of loads – that is, of end-use technologies – were presumed to be completely independent of the rest of the system. Provided they complied with basic technical protocols and the financial terms, they could buy and connect any technology they wished, whenever they wished, whatever its efficiency, whatever its performance. They were beyond the reach of system planners. 'Least-cost planning', as carried out by an electricity system, would remain purely theoretical and ineffectual unless a way could be found to bring the purchasers, owners, and users of loads into the process.

In the 1980s a way was found. It was called 'demand-side management' or DSM, the 'demand side' being the customer´s side of the electricity meter. Policy to foster DSM was initiated in the United States. Regulators mandated some traditional electricity systems to launch a variety of programmes intended to upgrade end-use technology such as lighting and motors, to deliver better services while using less electricity. Many different measures were introduced to win the cooperation of electricity users in DSM programmes. Some systems, for instance, offered customers high-efficiency compact fluorescent lamps free, or at much reduced cost. Some systems carried out energy audits on customer´s premises, identified potential improvements, arranged to implement them, and shared the value of the saved costs with the customers. From the late 1980s into the early 1990s a wide-ranging assortment of DSM programmes, particularly in the United States, were reported to have saved billions of dollars by improving performance and reducing waste on the customer´s side of the electricity meter. By the early 1990s electricity systems in Europe and elsewhere were beginning to introduce similar DSM programmes.

But DSM was intensely controversial. Some policy analysts deplored the entire concept, as arbitrary regulatory interference with traditional electricity business. Even those who were more sympathetic to DSM disagreed about how to implement it. A traditional electricity system drew its revenue from selling electricity by the unit, as measured at a meter. Trying to persuade its customers to use less electricity went directly against all prior assumptions and conditioning. Regulators also had to address a number of specific objections. For instance, promoting DSM cost the system money; and selling less electricity denied the system revenue it would otherwise receive. Should the regulator allow the system to recoup these costs from customers, and if so how – by charging, for instance, a higher price per unit of electricity? Should a system be allowed to charge yet more, to make a profit from

DSM, as an incentive to promote it? Policy disputes raged. Moreover, not all customers took part in or benefited from any given DSM programme. What about the ones who did not? If they paid higher prices per unit of electricity they would be doubly penalised; they would not receive the better end-use technology and service, and they would pay more for the poorer service.

Grappling with these and other tricky questions, DSM proponents tried to extend the discipline to encompass and compare not only 'demand-side' measures, on the customer´s side of the meter, but other categories of system expansion and upgrade. The extended concept came to be known as 'integrated resource planning' or IRP. The two distinguishing features of IRP are that it treats supply- and demand-side investments on the same basis and that in cost comparisons between different investment options it internalises environmental externalities. However, even as DSM and IRP were starting to demonstrate real achievements, and to find acceptable answers to at least some of the questions, other developments abruptly rendered the whole process essentially void. The entire concept of DSM/IRP as designed and pursued into the early 1990s was based on the structure and function of a regulated monopoly electricity system; and DSM/IRP was carried out as a result of a mandate from the regulator. Within only five years or so, however, most of the systems that had been testing DSM, in the United States and Europe, had embarked on liberalisation. The governments in charge broke up and abolished the monopolies, and dramatically altered the role of the regulators. In a liberalised competitive market context, DSM/IRP had neither a mandate nor a mechanism to implement it.

On the contrary, with its declared aim of making a unit of electricity cheaper, liberalisation made improved efficiency and higher performance of end-use technology less economically attractive and therefore less likely. In the ensuing years, with the spread of liberalisation, this dilemma has intensified. However, the situation is far from stable. Companies competing to sell anonymous units of electricity at a customer´s meter can compete only on price; in a genuine free market their profit margins shrink to vanishing. If a customer can change supplier in a month or less, the company´s customer base is alarmingly volatile, especially for a business that must rely on a vast array of fixed assets, in place and in operation on a continuous basis whether those assets are generating revenue or not. In recent years and months companies trying to cope with these circumstances have been changing names, structures, allegiances, and business plans at a hectic rate.

Some hopeful signs can already be identified. Companies are seeking to win the loyalty of customers, to establish new forms of business relationship, in transactions no longer necessarily determined by the metered flow of anonymous units of electricity. One approach with burgeoning potential is to sell not units of electricity but the complete suite of electricity services a customer requires, or indeed the complete suite of energy services, including those not explicitly involving electricity, on a contract basis – that is, a service contract, not a one-off commodity transaction. The key selling point for such a service contract is that the energy service company can offer the customer peace of mind and freedom from hassle. If the company can deliver on such a promise – a crucial point, needless to say – the customer´s loyalty is almost assured.

Activities focusing on improved delivery of services rather than metered commodity transactions have long been referred to under the label 'energy efficiency'. However, for substantial parts of energy systems, such as buildings, 'efficiency' has no operational meaning. A better description, avoiding spurious quantification and identifying better services, is 'high performance', for the entire system. This is especially relevant, for instance, if the energy input to the system is ambient or renewable and is not itself measured. Energy services are not commodity services; they tend to be infrastructure services. Policy should therefore be directed not simply to commodity transactions but to infrastructure, and especially to improvement of the energy service infrastructure.

In traditional fuel policy, 'fuel conservation' is a meaningful policy objective. Fuel is a commodity that can be measured in batches. When you use fuel for a purpose you can measure the useful consequences, as 'fuel efficiency'. 'Energy conservation', however, is a fundamentally misleading expression, as is 'energy efficiency' in most practical policy contexts, because much of the energy involved is ambient and not measured. In any case, the public and politicians have long since discounted 'energy conservation' and 'energy efficiency' as uninteresting. Decades of futile exhortation have blunted the impact of these concepts to minimal. A number of barriers impeding improved energy performance are well known. But the main problem is that people in general cannot be bothered. The most stubborn barrier of all is the 'hassle' factor.

This has important implications for energy policy in general, and for electricity policy in particular. Policy has to devise new mechanisms and processes to stimulate upgrades of the energy-service infrastructure, especially buildings. To overcome the 'hassle factor', policy must provide incentives for those with the requisite skills and competence to undertake the upgrading, as an economic and business activity – that is, as energy service companies. Policy can create opportunities to move from an 'energy' business based on buying and selling commodities by the batch to purchasing and delivering energy services on a contract basis. Compared to the precarious short-term business of competing to sell anonymous units of electricity at a customer´s meter, longer-term service contracts with loyal customers are attractive. A key aspect of policy to support this new approach is that governments, in turn, should be early customers for such energy service companies, calling for tenders to upgrade, operate, and maintain the government´s own buildings and other installations, including social housing. This will prime the pump for service companies, set a vivid example of new options and priorities, and – not incidentally – save taxpayers substantial sums. Tax regimes and other financial levers should be invoked to foster these activities, especially investment in improving the performance of buildings and other end-use energy facilities.

One possibility, ideally suited to the distinctive attributes of electricity, is to design and operate optimised integrated local systems to deliver services. This is a promising option in a variety of contexts. Many electrical loads, for instance computers and other electronics, and high-technology manufacturing plants, require electricity that is both highly reliable and of high quality, with minimal fluctuations. As noted earlier, even a traditional electricity system may not be able to meet these criteria. A liberalised system with less redundancy, and fewer maintenance personnel to deal with faults, is likely to be even less reliable. One increasingly attractive option is for the owner of sensitive loads to install on-site generation, to eliminate the problems that may come from the transmission and distribution network. Innovative technologies, such as micro-turbines and fuel cells with power electronics, can offer very high reliability and power quality, under the control of the owner of the loads. The extra cost of such on-site generation may be a form of insurance worth paying.

However, the owner of the loads probably will not wish the distracting additional responsibilities of on-site generation. Instead, the owner can contract with an energy service company to take over these responsibilities. The energy service company can bring to bear the appropriate combination of skills and technologies to design, install, and operate the requisite generation, to negotiate fuel and network connection contracts as necessary, and to operate and maintain the facilities, allowing the client to focus on core business without distraction.

Moreover, if the client agrees, the energy service company can also carry out an energy audit of the whole premises, and recommend and implement improvements in the technologies that use the electricity, including the building or buildings. Both the client and the energy service company will have a substantial incentive to optimise the entire local system, to deliver the desired energy services with the most effective combination of technologies. If the plan is for entirely new premises, so much the better; the energy services company should be involved from the inception of the plan. The aim will be to achieve the requisite reliability not of electricity but of the services themselves – illumination, motive power, refrigeration, data processing, and so on – at the lowest possible cost and with the most acceptable environmental impact. Thinking of the whole integrated local system, and looking to optimise it accordingly, becomes feasible and appropriate again, as it was initially for Thomas Edison. This is possible because electricity is an energy carrier that can be generated anywhere, indeed as locally as desired.

Another aspect of increasing concern to policymakers is so-called 'energy security'. In the context of electricity, as markets are liberalised, will sufficient investment be made in new supply capacity in order to meet growing demand, and will the reliability of networks be maintained? Although the advent of electricity market liberalisation has generally seen the demise of IRP, such planning tools, now used in a different way, may find a new role. In the past, some regulators mandated IRP; the regulatory reviews recognised the costs that traditional systems thereby incurred. In the future, some argue, IRP will be used to publish demand and supply scenarios that indicate various investment possibilities and opportunities. Some countries, for example Australia, are beginning to do this. Governments can mandate the market operator, the system operator, or the regulator to fulfil this function. In a liberalised market, IRP can provide timely warning of potential investment shortfalls; it can also stimulate governments and regulators to facilitate new investment through auctions or through improving the investment environment.

Electricity generated in central stations and delivered over long networks is especially vulnerable. Because electricity is not a fuel but a physical phenomenon, a disruption anywhere in the system can interrupt the flow of electricity essentially instantaneously; a sufficiently severe disruption can crash the electricity system of an entire country in seconds. Vulnerability to immediate disruption of electricity supply may best be minimised by generating it as close as possible to the point of use. Security considerations may thus favour the move towards more decentralised electricity systems. In general, however, the best way to reduce vulnerability to interruption of delivery of all energy carriers, including oil, gas, and electricity, is to reduce reliance on these energy carriers – that is, to upgrade energy service infrastructure, to get better performance for less fuel or electricity.

This means that the most important policy measures to improve energy services, and especially electricity services, are those that influence infrastructure development, including for instance measures affecting building standards, asset accountancy, taxation of investments, and other powerful levers not usually recognised as part of energy policy, much less electricity policy. Improving energy services in general, and electricity services in particular, for economic and environmental benefit, will require a major policy reappraisal. Expanding the scope of relevant policy is long overdue.

Widening Access to Electricity Services

The most significant failure of traditional electricity has been its failure to reach two billion people – one third of humanity. From one viewpoint, liberalisation and market-based electricity policies may aggravate this problem. The people still without electricity are the poor, both in deprived urban areas and in rural areas, especially in developing countries. Basing electricity policies on market criteria, and ability to pay, will deepen the gulf between those who can afford the benefits of electricity and those who cannot. The issue is a direct and intensifying challenge to policymakers around the world.

Even in OECD countries, the plight of the poor is long since of concern to those who accept that a valid and continuing role of government is to look after the less fortunate in society. People in poor neighbourhoods often have serious difficulty paying bills for electricity and fuels. As a result, many indigent and elderly people who cannot afford to heat their homes die of cold every winter. A common approach has been for governments to offer modest grants, called ‘fuel supplements’ or the like, to help them to pay these bills. But the poor tend to live in dwellings that are damp, draughty, and structurally inadequate, from which heat escapes almost as fast as it is injected. Fuel supplements do nothing to rectify this fundamental infrastructure problem. The emergence of energy service companies offers a different and more constructive possibility.

A government that is concerned, say, about poor-quality social housing can call for tenders from energy service companies, to deliver a declared level of comfort, illumination, and other services to the inhabitants of the housing. The successful tender will receive a contract of suitable duration, paid for from the government´s social budget. The energy service company can then decide the best way to deliver the desired services. In most instances the first phase will be to upgrade the buildings themselves, with insulation, draught proofing, and similar measures, and to replace inefficient heaters, boilers, and lighting. In this way the government funds, rather than being squandered on the running cost of heat that is lost almost immediately, become investments. They pay for long-lasting improvements to the residential building stock and infrastructure, the parts of the local energy system most in need of improvement. Moreover, government funding for such essential improvements also prime the pump for energy service companies, by creating new markets for their business activities.

Much is still made of the 'public service' aspect of electricity, notably in countries reluctant to liberalise. Some commentators insist that only a traditional monopoly system can deliver this public service adequately and equitably. Others, however, point out that the public wants the services, not just the electricity. Higher performance of the whole electricity system, including the end-use technology, delivers better service at lower cost, whoever pays. If liberalisation offers a way to stimulate whole-system improvement, the opportunity ought to be seized. Integrated optimised local systems will be promising early candidates.

In many developing countries, the record of traditional electricity organisations in rapidly expanding access to electricity is poor. In many African countries, less than 10 percent of the population have access. Some notable exceptions include South Africa, where the government-owned Electricity Supply Commission Eskom and municipal distributors have increased access from less than one third to over 70 percent of households in only seven years. But this is an unusual case, made possible by an organisation owned by government but run commercially, with a wide customer base and hence the opportunity to effect significant internal cross-subsidies with encouragement from a newly instituted democratic government (Box 3-3).

Electricity liberalisation is unlikely to improve the access of poor households to electricity – *unless* it includes specific policy and regulatory instruments. For instance, the licence conditions of private distributors may stipulate connection targets. Subsidies will remain important. In most OECD countries, subsidies brought about universal access to electricity, particularly in rural areas, a point often forgotten. In many developing countries, wider access to electricity will depend on the judicious use of subsidies, preferably to offset the capital cost of the connection, rather than the ongoing energy and operating costs. A degree of cross-subsidisation of tariffs may also be socially desirable – but the cross-subsidies must be transparent and well targeted, and should not prejudice efforts to improve economic efficiency and the reduction of costs. In South Africa, internal electricity-industry cross-subsidies are being reduced and an electrification fund has been established using tax revenues

Box 3-3
Electrification in South Africa

The experience of the electrification programme in South Africa over the past decade provides an interesting example of how significant progress can be achieved in widening access to electricity for the urban and rural poor in developing countries. It also provides lessons on how electrification can be advanced as the electricity supply industry is restructured.

The rate and scale of the electrification programme in South Africa is unprecedented. Between 1992 and 2000, the proportion of households with access to grid-connected electricity doubled from about one third to just under two thirds, with 75 percent of urban, and 46 percent of rural, households electrified.

The spur to this impressive programme was the advent of democracy in the early 1990s. The Reconstruction and Development Programme of the African National Congress, which came to power in 1994, promised 2.5 million new connections over a five-year period. In fact, these targets were exceeded; in the period 1992–2000, 3.5 million households received a new electricity connection.

Of the new connections, 60 percent were made by the state-owned national utility, Eskom; the remainder were made by local governments. Eskom has an effective monopoly over generation and transmission, and distributes about 60 percent of electricity to customers; 237 municipalities distribute the balance.

Up until year 2000, Eskom funded the entire electrification programme, either through internal subsidies – or through transfers to an electrification fund that the National Electricity Regulator has allocated to municipalities. The average annual capital expenditure on this programme has been around US$130 million and the average cost per connection has been around US$290.

National policy has been that the capital cost of connections should be subsidised. However, there have also been unplanned cross-subsidies in operating costs. At the beginning of the programme it was estimated that the average monthly consumption of newly connected, low-income households would be 350 kilowatt hours per month (compared with an average of 750 kilowatt hours per month for a middle-income family in South Africa). In practice, average monthly consumption has been less than 100 kilowatt hours and often as low as 50 kilowatt hours per month.

Nearly all of these new connections have used pre-payment technology – customers buy tokens or top-up electronic cards to activate their electricity dispenser. The costs of the electricity supply and use were to be recovered through a flat energy unit charge. Many connections involve informal houses (shacks) and use pre-wired ‘ready boards’ – typically with a few lights and plug points.

The electricity industry has been able to fund and cross-subsidise this massive electrification programme, largely because there is a substantial industrial customer base that accounts for the bulk of electricity sales. Unit cross-subsidies from these customers have been proportionately small and politically acceptable.

In 2002, the South African government started to reform and restructure the electricity supply industry. The municipal electricity distributors are being rationalised into six regional electricity distribution companies. Eskom has been corporatised in preparation for partial privatisation and the introduction of competition. Eskom now pays taxes and dividends to government, and electrification is being funded from a new National Electrification Fund that gets its resources from the government Treasury. A National Electrification Programme Management Unit has been established as well as a National Electrification Business Planning and Operations Management Unit. Electrification targets will continue to be set for the industry. Thus the electrification programme will continue, despite the pending liberalisation of the electricity market in South Africa. Explicit policy and regulatory instruments have been put in place to ensure the continued commitment to move to universal access to electricity in South Africa.

In addition to the grid-electrification programme, there has been an active off-grid programme using photovoltaic technology. Between 1994 and 2000, 1,350 schools were electrified with off-grid systems. Many rural health clinics have been equipped with solar systems. In addition, government has awarded subsidy concessions to private industry service providers in five geographic areas to supply solar home systems as well as supplementary fuels such as liquefied petroleum gas. These are not geographically exclusive concessions; other companies may also operate in the areas. However, the concessionaire in each geographic area will receive a subsidy of US$320 per installation. The rationale is to assist service providers in building up adequate service infrastructure and to move towards financial sustainability. Supply targets and service standards have been set and performance will be monitored.

The concession contractual framework has been less then perfect. For example, there was little entry competition, and firms were not required to bid competitively on subsidy requirements. The opportunity to encourage efficiency and lower costs has not been maximised. Nevertheless, considerable innovation is emerging in the systems and vending technology employed. Most suppliers have adopted a fee-for-service approach rather than the outright sale of solar home systems.

The electrification programme in South Africa demonstrates that it is possible to make substantial progress in widening access to electricity services for the world's poor, even within a restructured and liberalised electricity market, by using various institutional models and combinations of grid and off-grid technology.

and dividend flows from Eskom. A national electrification planning authority, attached to the fund, allocates subsidies according to connection targets.

Electricity markets can offer new and innovative mechanisms for widening access. Subsidies might be auctioned: the firm requiring the lowest subsidy wins access to subsidy funds and the concession to supply to customers. The emphasis might be placed on providing energy services, rather than simply selling units of electricity. Developing countries offer interesting examples in which solar home systems and liquefied petroleum gas are provided on a fee-for-service basis. Concession holders or private companies invest in infrastructure, and households pay for the provision of lighting, media services, and cooking fuels. Box 3-4 describes how electricity has gradually been supplied to the *favelas* – shantytown dewellings – in São Paulo, Brazil.

Box 3-4
Bringing Electricity to the *Favelas*

Until late in the 1970s, only a small proportion of *favelas* dwellings in São Paulo, Brazil, had regular access to the electricity grid. Most squatters had no access at all and used candles or kerosene lamps for lighting; the few who did have access had obtained it illegally through middlemen.

While squatter organisations had long demanded the provision of electricity services, both the electric utility and the city administration opposed electrification in *favelas*, with the excuse of inappropriate local conditions. Official policy was to remove squatters. But when the continued spread of *favelas* made it obvious that general eradication was unfeasible, providing public services to these areas finally began to be considered.

In 1979, the city administration and the electric utility – now belonging to the state government – made an agreement to install electricity in *favelas*. Eletropaulo, the utility, would connect the shacks, with kits made with simplified technology whose costs – roughly US$150 each – would be subsidised. Within a few years, some 100,000 shacks were connected. No meters were installed, since the costs of metering – US$30 to 40 – were considered to be too high for shacks with low consumption. Dwellers were charged a subsidised flat rate, equivalent to the monthly consumption of 50 kWh – a bill of approximately US$1.00. At the time, residential electricity services in Brazil had a progressive tariff: higher levels of consumption became gradually more expensive. The decision to charge only a nominal sum, subsidised by larger electricity consumers, was a political one by the Governor of the State of São Paulo, not the electric utility.

Access to electric energy brought real gains in quality of life. Improved lighting was particularly well received; it facilitated home cleaning and taking care of children and eliminated smoke and soot, as well as the fear of fire accidents. Improvements were also noticed by those who had got rid of the unreliable electricity supplied by intermediaries in favour of the new service. Moreover, the squatters' access to the credit system became easier, because the electricity bill, which contained name and address, worked as a residence document.

Research conducted in 1991 verified that television sets were already present in almost every home, refrigerators in 80 percent. Monthly average consumption per dwelling was 175 kWh – comparable to consumption by low-income dwellings outside *favelas*. In other words, consumption was much higher than was actually paid through the flat rate.

Thus in the early 1990s, squatters could already be looked at as normal consumers, and that justified the installation of meters, so that each dwelling could be charged its actual consumption. But such changes were postponed by the utility, possibly out or fear of squatters´ reactions. A decade later, as a result of a general reorganisation of the electric sector in Brazil, new rules for low-income consumers have been set and changes in shanty town billing are eventually likely to happen.

In short, the electrification of *favelas* in São Paulo was a successful program. Of course, electrification programs are not supposed to solve broader problems, like public housing and income distribution policies. But providing regular electricity supply opened the way for genuine improvements in the quality of life of a large poor population, as is reflected in the rapid growth in the level of electricity consumption.

Conclusion: Electricity Policy for Sustainable Development

Sustainable development has many aspects that do not explicitly involve energy, much less electricity. Nevertheless, getting energy right may render other aspects more achievable; and getting electricity right offers a distinctive and potent opportunity to reshape the use and provision of energy of all kinds in more sustainable directions. The turbulent uncertainty now sweeping through electricity policy world-wide may be disconcerting and unnerving; but it also opens the way to new and imaginative thinking, much less constrained by traditional concepts and assumptions.

Remember that electricity is different. It is not a fuel, nor a commodity. It is a physical phenomenon and can be generated anywhere, at a price. Traditional electricity, generated in large remote central stations and delivered as a commodity to users over long networks, arose because with the technology then available, and its economies of unit scale, this arrangement was the cheapest way to provide electric light, electric motive power, and other electricity services. The monopoly franchise made the large-scale long-term investments feasible, because captive customers bore the risks. But the structures, status, and functions of traditional electricity now face a mounting challenge from technical and institutional innovation. In response, electricity policy must cope with the consequent problems, and seize the emerging opportunities.

Technical innovation now offers a burgeoning catalogue of technologies with attributes very different from the traditional – generators that are small, clean, and reliable; high-performance end-use technologies to deliver high-quality services; network technologies that can accept, transport, and deliver both AC and DC as appropriate, at powers from gigawatts to microwatts; and monitoring-and-control technologies to integrate system operations and transactions. If we were starting now to electrify society, with technologies now or soon to be available, electricity systems would look and function very differently. They would probably be decentralised both technically and institutionally, with the emphasis on integrated optimised local systems using mainly local resources and under mainly local control. Both the physical and the financial structures and relationships would differ profoundly from those of tradition that still prevail. So would electricity policy.

Therein, however, lies the major challenge for policy: how to retain the best of traditional electricity while realising the promise of innovation. Electricity policy can no longer be made and implemented exclusively from the centre. It must now involve the active participation of many different players, who probably have different and in some cases conflicting agendas. It must therefore be formulated openly and transparently, as an outcome of dialogue and debate. Traditional electricity and innovative electricity are not well suited one to the other; both technically and institutionally they are compatible only to a limited extent, and then with difficulty. But in most parts of the world they must co-exist, certainly for decades to come, and policy must smooth this potentially incoherent linkage. At the very least, established tradition should not be allowed to stifle innovation, as a backlash to problems with liberalisation.

Some policy measures are reasonably clear, albeit bitterly controversial. For instance, governments should phase out the large existing subsidies, tax advantages, and other one-sided financial benefits they still grant to traditional fuels and technologies, to allow innovative fuels and technologies to compete on equal terms. Instead, to rectify the position somewhat, governments should offer subsidies of well-defined limited scope and duration to assist innovative technologies to achieve commercial acceptance, and to be incorporated into electricity systems as the systems evolve.

Policy should recognise that concepts and measures appropriate to commodities that can be stored, bought, and sold in batches, priced by the unit, may not be appropriate to electricity. Electricity requires an entire system of assets, in place and in continuous operation, to deliver the service desired at a given instant. It is a function of infrastructure, not a commodity. This is especially so in the case of renewable technologies such as wind power and photovoltaics that convert continuous natural energy flows into electricity. Electricity services too tend to be asset and infrastructure services, not commodities. The most effective policy measures, such as tax regimes, are therefore likely to be those that apply to investment in, and management of, assets and infrastructure, rather than those that apply to one-off batch transactions in commodities.

Because electricity is inherently a system concept, policy must pay close attention to the structure, function, and evolution of the system. One critical feature of electricity systems, already controversial and growing more so, is that of access to and use of the network by generators and users. Existing traditional networks were designed to carry large quantities of electricity from very large centralised generators to much smaller loads, and to subdivide the electricity accordingly, in a radial one-way pattern throughout a monopoly franchise area. These networks were never intended to serve as a matrix for competitive market-based transactions. In liberalised contexts, however, they are now operated this way, a development that may prove difficult to sustain. Moreover, innovative decentralised electricity needs networks that are meshed and multiply interconnected, and can carry electricity in either direction. Over time, electricity policy must prepare to tackle the major challenge of transition from traditional to innovative networks, while keeping the lights on. Integrated optimised local systems may be a crucial intermediate step.

As traditional electricity systems are restructured into liberalised electricity markets, and as technical innovation enables a shift to very different configurations for electricity systems, providing social and environmental public benefits requires renewed attention. These potential benefits include expanded access to electricity services, increased investment in high-performance energy infrastructure, guaranteed energy security, and a cleaner and more sustainable environment as a consequence of the development and application of new and renewable technologies.

Liberalised electricity markets and new technology do not guarantee the expanded provision of public benefits. To protect, advance, and expand social and environmental benefits will require explicit policies and regulatory instruments. The greatest challenge is to bring electricity services to the two billion people currently without. Developing countries need clear policies that specify electrification targets; such policies should direct expenditure from donors and government and from sensible levels of electricity industry cross-subsidies into electrification funds to expand electricity sustainably. Appropriate design of electricity markets and regulatory instruments can strengthen this effort, through incentives and obligations, to extend access and invest in improving energy service infrastructure.

An important policy challenge for developing countries is to filter the experience of electricity market liberalisation in industrialised and emerging market economies, and to apply those features of market restructuring that respond to the needs and problems particular to developing countries.

A second challenge is to utilise emerging technologies and system configurations. Technical innovation is leading to smaller, cleaner technologies; more decentralised systems; versatile networks with more complex and responsive control systems based on new information and communication technologies; and high performance end-use technologies and energy service infrastructure. Electricity policy in developing countries should facilitate the transformation of their traditional electricity industries to the increased adoption of new technology and system configurations. Policy should encourage not merely the sale of more electricity to more users, but the delivery of energy services infrastructure to improve welfare and productive opportunities for the world's poorest in a sustainable manner.

The distinctive attributes of electricity, and the upheaval now affecting electricity policy world-wide, open the way for electricity to play a leading role in the emergence of energy policy for sustainable development. We do not yet know what sustainable electricity may look like. But we have ample evidence about what it will not look like. Traditional electricity, for all its successes, has failed to reach two billion people; and its key technologies face financial and environmental problems that may become insuperable. Traditional electricity cannot be sustainable. We must do better; and we can.

For Further Reading

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4 Energy Technologies and Policies for Rural Development*

AMULYA K.N. REDDY

If the goal to be achieved by *any* energy system is sustainable development, then *the goal for rural energy systems is that they must be instruments of sustainable rural development*. Rural energy systems, therefore, must advance rural economic growth that is economically efficient, need-oriented and equitable, self-reliant and empowering, and environmentally sound.

The stress on equity means that rural energy systems must first and foremost promote poverty alleviation and improved living conditions for the poor, as measured by the Human Development Index (HDI). The HDI measures a country's achievements in three aspects of human development: longevity, knowledge, and a decent standard of living. Improving these aspects of human development, and therefore the HDI, has three crucial dimensions: *equity* based on a marked increase in access of poor to energy services, *empowerment* based on strengthened endogenous self-reliance, and *environmental soundness*. Thus for an energy system to be in the interests of the rural poor, it must:

- Increase their access to affordable, reliable, safe, and high-quality energy.
- Strengthen their self-reliance and empower them.

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* Based on a presentation at the Second Meeting of the Global Forum on Sustainable Energy on November 28, 2001, at the International Institute for Systems Analysis, Laxenburg, Austria; and on 'Rural Energy: Goals, Strategies and Policies', *Economic and Political Weekly* 34, no. 49, December 4, 1999, pp. 3435–45.

- Improve the quality of their environment (starting with the immediate environment in their households).

Strategies for Rural Energy

The strategies for rural energy systems (i.e., the broad plans to reach the goal or objective) include the following:

- The *reduction of arduous human labour* (especially the labour of women) for domestic activities and agriculture.
- The *modernisation of biomass* as a modern energy source in efficient devices.
- The *transformation of cooking* into a safe, healthy, and less unpleasant end-use activity.
- The *provision of safe water* for domestic requirements.
- The *electrification of all homes* (not merely villages).
- The *provision of energy for income-generating activities* in households, farms, and village industries.

These strategies pertain to *what* rural energy systems should achieve. But there should also be strategies that pertain to *how* these products should be achieved, i.e., to the *process* that should be followed. There are three process strategies for rural energy:

- Government facilitation and enabling support.
- Individual initiative as far as possible through the market.
- Village community monitoring and control.

The standard approach to the establishment of new infrastructures (for example, rural energy systems based on new technologies) has been for governments to take the initiative. This approach often ends up with the emergence of new government agencies and accompanying bureaucracies that may be plagued by red tape, delays, or even corruption. The result has been the more recent trend toward liberalisation.

Many claim that the market is the best solution to the problem of establishing and running economic activities such as the infrastructure. Hence the slogan, 'Leave it to the market!' The market may indeed do an excellent job of allocating men, materials, and resources; it does not, however, have a very successful record at safeguarding equity, the environment, the long-term, or research, development, and dissemination of new technologies. The market is thus not an adequate instrument for addressing tasks characterised by a low discount rate; it will have to be assisted by the State.

There is, however, a third option, namely, encouraging individual initiative subject to local community control. It has been shown that it is possible to realise 'Blessing of the Commons' situations[1] (the converse of the well-known 'Tragedy of the Commons') in which the costs that an individual/household experiences for not preserving the commons far outweighs whatever benefits there might be in ignoring the collective interest. In other words, *there can be a confluence of self-interest and collective interest* so that the interest of the commons is automatically advanced when individuals pursue their private interests. Thus *individual initiative plus local community control* is a third option that can be as, if not more, effective than either the government or the market acting alone.

The Relationship between HDI and Energy

For rural energy systems to advance sustainable rural development, the emphasis must be on *energy services* – not merely on energy consumption (or supply) as an end in itself. The focus has to be on energy services that improve the Human Development Index *directly* (cooking, safe water, lighting, transportation, etc.) as well as *indirectly* via employment and income generation (motors, process heat, etc.).

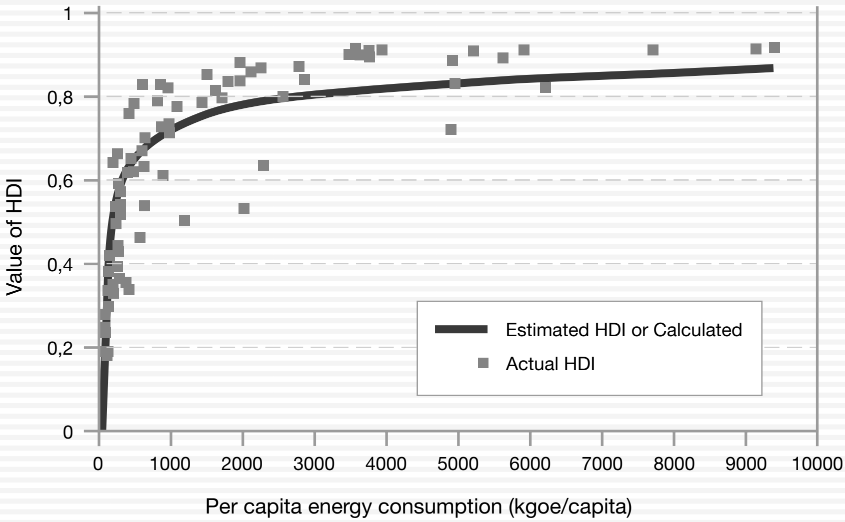
The impact of energy on the HDI depends on the end-uses of energy and on the tasks that energy performs. The direct impact of energy is associated *inter alia* with, and is produced by, cooking, supply of safe water, and lighting. The indirect impact of energy is associated with, and is produced by, electric drives (e.g., motors, pumps, compressors) and process heat (processing industries).

The role that energy can play in improving the HDI is not merely a matter of hope or conjecture. There is an empirical basis to the relationship between HDI and energy. Strictly speaking, the relationship must be between energy *services* and HDI. However, if end-use efficiency is virtually constant, energy *consumption* can serve as a proxy for energy services (Figure 4-1).

The relationship between HDI and energy has several important implications. The relationship can be considered to consist of *two regions* (Figure 4-2). The figures shows that in region I – the 'elastic region' – the slope $\delta(HDI)/\delta E$ of the HDI vs E curve is high; *large* improvements in HDI can be achieved with *small* inputs of energy (small improvements of energy services), making the HDI-energy (benefit-cost) ratio very high. In region II – the 'inelastic region' – the slope $\delta(HDI)/\delta E$ of the HDI vs E curve is low; even *large* inputs of energy (large improvements of energy services) result only in *marginal* improvements in HDI, i.e., the HDI-energy (benefit-cost) ratio is very low.

In the 'elastic' region I, enhanced energy services lead *directly* to the improvement of HDI. But the impact of energy on HDI can also be indirect. Improvements of energy services can yield increased income that can be used to 'purchase' HDI improvements. Thus in the 'inelastic' region II, enhanced energy services can lead *indirectly* to the improvement of HDI via income generation. In the 'elastic' region I,

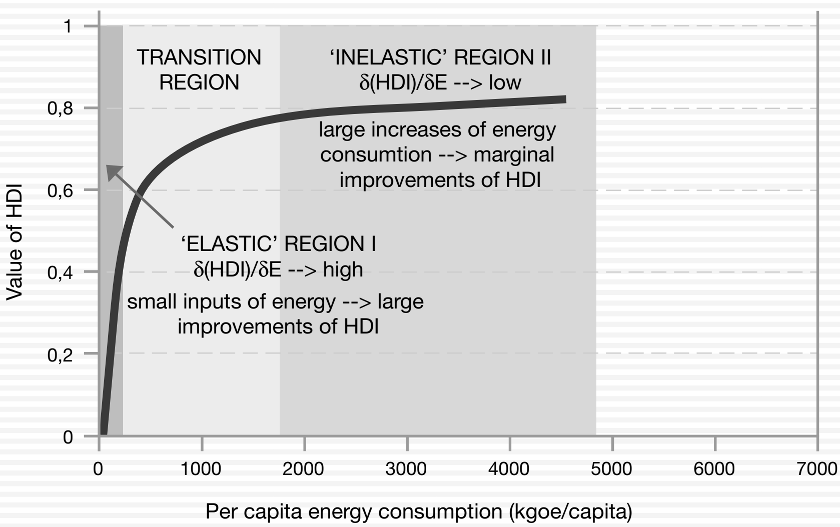
FIGURE 4-1: RELATIONSHIP BETWEEN HDI AND PER CAPITA ENERGY CONSUMPTION (1991–1992)



Note: Data for 100 developed and developing countries.

Source: Calculations by Carlos Suarez based on data in United Nations Development Program.

FIGURE 4-2: 'ELASTIC' & 'INELASTIC' REGIONS OF HDI VS ENERGY CONSUMPTION



the coupling between HDI and income (used to defray the operating costs of energy devices) can be reduced. In fact, HDI can even get decoupled from income so that HDI increases can be achieved without income increases. A shift from kerosene lamps to electric lights is an example of improvements in energy services at operating costs comparable to, or even less than, the costs of using kerosene lamps.

In the ‘inelastic’ region II, HDI is coupled to income. But income-coupled improvement of HDI depends on important conditions being satisfied. The improvement of HDI via income generation depends on what the income is used for. Is it used for HDI improvement? For liquor? Gambling? Conspicuous consumption? This in turn often depends on which gender gets the income – women tend towards expenditures that improve the HDI of their families, particularly their children, i.e., they use a much lower discount rate than men use.

Thus the implication of the ‘elastic’ and ‘inelastic’ regions is that in the elastic region increased energy services guarantee direct improvement of HDI, whereas improvement of HDI via income depends on what the income is used for.

Approaches to Poverty Alleviation

The relationship between energy and HDI has profound implications for the strategy for alleviating poverty. In the 1970s, the emphasis in poverty alleviation was on direct satisfaction of basic human needs. However, these concerns were swept aside by the wave of liberalisation. It was believed that income generation was the magic wand that would make poverty vanish. Macroeconomic growth became the standard approach to poverty alleviation. However, this did not work because the benefits of economic growth are absorbed far too slowly by the poor. Attention was then turned to human capital investment, but even this is a slow process. Direct poverty alleviation is a much surer method of improving the HDI than the indirect route of income generation and human capital formation in the hope that the income generated and the human capital utilised will lead to a trickling down of benefits to the poor. The direct improvement of HDI is a necessary condition for launching an indirect improvement via income.

The ‘elastic’ region of the energy-HDI relationship shows that dramatic improvements in HDI can be achieved with very small investments of energy. In fact, it is possible to get a very rough estimate of the energy cost of an ‘elastic’ improvement of energy services for the poor. Assume that this necessary improvement of energy services in tropical countries consists of a) safe, clean, and efficient cooking with liquefied petroleum gas (LPG) or a LPG-like fuel and b) home electrification for lighting, space comfort, food preservation, and entertainment. The energy required for cooking would be about 2.3 gigajoule per capita per year, or about 73 watts/capita[a]. The electricity for lighting, fans, etc., at twice the consumption of 33 kilowatt hours per household per month currently found in Karnataka State, South India,

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[a] Watts/capita is an abbreviation for watt years/(capita year).

would be about 18 watts/capita. This leads to a total of 91 watts/capita that can be approximated to about 100 watts/capita[b]. Thus, *as little as 100 watts/capita is adequate to achieve a dramatic revolution in quality of life corresponding to safe, clean, and efficient cooking with a LPG-like fuel and home electrification for lighting, fans, a small refrigerator, and a television*. This 100 watts/capita is only about one tenth of the level required to support a western European living standard with modern energy carriers and energy-efficient technology.[2]

Energy Sources and End-Use Devices

Attention must be focussed not only on the supply aspects of the energy system but also on the demand aspects. Rural energy systems must be considered to consist of whole 'fuel' cycles from energy sources through energy carriers via transmission/ transport to distribution to end-users for utilisation in end-use devices to provide energy services. There must be an emphasis not only on energy sources but also on efficient end-use devices.

The primary sources of energy are fuels and electricity – fuels for cooking (stoves) and for process heat (boilers/furnaces/kilns) and electricity for lighting (lamps) and for electric drives (motors, pumps, and compressors). There are also opportunities for cogeneration, i.e., the combined production of heat and power.

The thrust must be on energy sources and devices that are renewable, biomass-based, universally accessible, affordable, reliable, high quality, and safe. Special attention must be devoted to sources that are locally available, small scale, decentralised, and renewable, and systems that are amenable to and enhance local control.

The choice of energy sources (fuels and/or electricity) must be guided by preferences for sources that:

- Give the entire rural population, but particularly the rural poor, access through micro-utilities and community-scale systems for high-density settlements and through home/household systems for individual homesteads in settlements with low housing density.
- Are compatible with high-efficiency end-use devices.
- Lend themselves to cogeneration (i.e., the combined production of heat and power).
- Are decentralised/locally available to strengthen self-reliance and to empower people/communities.
- Are renewable and promote environmental soundness.

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[b] This number is in broad agreement with the estimate of Robert Williams (Princeton University, personal communication) of slightly more than 100 watts/capita consisting of 87 watts/capita for cooking with clean LPG, 3.75 watts/capita for five CFLs for lighting, 3.13 watts/capita for a colour television, and 13.65 watts/capita for a refrigerator.

Access to (and penetration by) individual homes is determined by the affordability of the energy source – costly sources restrict access to the affluent few, and cheap sources facilitate 'universal' penetration. Household systems commandeer capital, energy resources, and entrepreneurship, and may even pre-empt the subsequent establishment and operation of micro-utilities (that increase access by the rural poor).

The following questions are therefore important in the choice of end-use devices. Do they directly improve the HDI? Do they generate income that (used constructively) improves HDI? Are they accessible to the rural poor? Do the devices have a low enough first cost and operating cost? Or do they have the same/lower operating cost as traditional devices after innovative financing (to convert unacceptable initial costs into affordable operating costs)? Do they benefit women? Are they environmentally sound?

Elitist or Egalitarian Character of Sources and End-Use Devices

If rural energy systems have to be instruments of sustainable rural development, how a rural energy technology distributes benefits must be scrutinised. Equity impact assessment (EqIA) statements are important. Those implementing technologies with a goal of sustainable development have an obligation to anticipate and examine the distributional or equity implications of the technology they are promoting. In contrast, those who pursue technologies, particularly renewable energy technologies (RETS), as ends-in-themselves to advance global environmental objectives, do not have this obligation to consider distributional or equity implications.

Consider the dissemination of photovoltaic solar home systems (PV SHSs) in rural India. An analysis of the 1999 costs of four-light, 37-watt photovoltaic home systems and the income distribution pattern in rural India shows that only about 7 percent of households have the income required for such systems. Assuming that only half of households that can afford the PV SHS are prepared to switch, it appears that the market for such systems is restricted to much less than the richest 5 percent of rural households. Smaller systems have much greater potential for penetration. About 17 percent of households have the income to afford two-light, 20-watts systems, and about 75 percent of households can afford one-light, 10-watt systems. (see Annex A)

Since PV SHSs are inaccessible to the rural poor, it is tempting to dismiss them as *elitist* energy sources/devices. However, if the purpose of a PV SHS is not merely to improve the quality of life of the household, but to illuminate after-sundown activities that augment income (for example, weaving baskets), then the elitist characterisation may not apply. The income generated under illumination by the PV SHS can more than pay for the investment in the light.

Another reason not to engage in hasty judgements about the elitist or egalitarian character of energy sources and devices is that technological advances and organisational learning can bring about major cost reductions in the cost of emerging, not-yet-mature technologies – a point well illustrated by the declining trend in the cost of PV modules. This means that decisions must be made on the basis of future costs, rather than present costs that are bound to decline. Declining costs can erode the elitist character of sources and end-use devices and strengthen their egalitarian character.

If particular sources and end-use devices are elitist, then they will a) bypass the rural poor, b) fail to alleviate poverty, c) make a negligible contribution to energy systems and d) hardly mitigate negative environmental impacts. They can, however, offer a small, high-profit market for profit-making enterprises.

The skewed distribution of the benefits of some technologies leads to important questions such as the following. Do elitist sources/devices pre-empt the possibility of dissemination of affordable sources/devices for the rural poor? Do they hijack capital that would otherwise be used for poverty alleviation? Do they divert resources that would otherwise be used for the rural poor, for example, do household-size biogas plants use up the dung that could be used by a more cost-effective community-scale plant? Is there a level playing field for elitist sources/devices and sources/devices for the rural poor? Are banks and financial institutions biased towards elitist sources/devices?

Financing Rural Energy Technologies

A widely held, but erroneous, belief is that, without subsidies, the poor cannot afford to pay for basic services.[c] In fact, however, the poor already pay for services – food, water, lighting, etc. – either with money or with their labour time. So the question is whether the poor will choose an alternative way of obtaining the service in preference to their current option. Even when they are getting a service for 'free', i.e., without financial cost, they devote their labour time for which there may be other more pleasant and/or lucrative options. They may well choose to pay for a service that they normally get 'free'. For example, rural households have preferred to pay for priced safe water rather than use 'free' water from unsafe sources.

For most services, even the poorest rural households can afford to make some payments commensurate with what they are currently spending. And if they are currently getting something for 'free', there are opportunity costs associated with the time they spend to obtain the service. The real or opportunity costs of traditional practices are an important benchmark because they invariably define the maximum amount that the household is willing to spend. Thus the operating costs of traditional devices (e.g., kerosene lamps) are a sort of upper bound for the costs of an alternative technology. The cost problems associated with a new technology stem from the capital costs of acquiring it rather than from the operating costs. Hence, innovative financing can play a major role. Loans (not necessarily soft loans), leasing, etc., can convert unacceptably high initial capital costs into manageable affordable operating costs.

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[c] Actually, subsidies granted in the name of the poor in India often end up going to the better off. For example, free electricity to rural areas goes primarily to farmers who are rich enough to own an electric pump for pumping irrigation water.

In the case of energy, the technological opportunity is upper-bounded by the maximum possible household expenditure on energy (say 15 percent). After a favourable financing scheme, the operating costs of the proposed (improved) devices (e.g., electric fluorescent lights) can be even lower than the operating costs of traditional devices (kerosene lamps). Technology, therefore, can widen the window of opportunity.

Converting capital costs into affordable operating costs requires investments from financial institutions. Fortunately, there are financial institutions/banks/donors that have the capacity to provide the financial inputs for innovative financing. Their backing enables rural banks to provide loans for purchase or lease of energy-efficient devices (stoves, lamps, drives, boilers/furnaces/kilns, etc.) to improve HDI directly as well as indirectly via income generation. However, rural banks may not be accustomed to developing programs to help turn capital costs into operating costs, and may have to go through a learning process.

Similarly, local-level implementing agencies/bodies may not have the expertise or capacity to discharge their new responsibilities, making new energy enterprises necessary. These new energy enterprises must tackle the challenges of marketing non-conventional energy sources and/or energy-efficient devices. New institutional arrangements may also be required. For example, concessions may have to be allotted to enterprises to deliver services to households in a specific region with an obligation to serve even the poorest households. Joint ventures may have to be established to set up decentralised/ renewable energy systems compatible with high-efficiency devices accessible to the rural poor. It may also be necessary to establish and develop micro-utilities (particularly those run by women) and to commercialise decentralised/renewable energy sources and energy-efficient devices.

Time Horizon: The Near, Medium, and Long Term

Identification of technological options for energy sources and devices depends very much on the time horizon. Unfortunately, two extreme trends can be observed. Because grassroots rural development workers are preoccupied with the immediate problems of the people with whom they work directly, they tend to choose technological options that are available right off-the-shelf. Totally preoccupied with the present, they tend to use a very high discount rate for their technological decisions. In contrast, technical experts are excited by technological possibilities, and talk about futuristic solutions as if they are already valid. Being totally preoccupied with the distant future, they use a very low discount rate for their technological decisions. Thus grassroots rural development workers are moved by real human beings and restrict themselves to ‘band aid’ or quick-fix remedies, forgetting about ultimate sustainable solutions. Technologists – enamoured with technological innovations even though they may take a long time to become realities – are little concerned that people remain in their current misery while they are waiting for the promised ideal technology.

Obviously, an either-or approach must be avoided. Starting from the present technology (the initial condition), three types of technology are needed for each energy-utilising task. A *near-term* technology should lead to immediate improvement compared to the present situation. A *medium-term* technology to achieve a dramatic advance should be available in five to ten years. And a *long-term* technology should prevail after twenty to thirty years and provide an ideal sustainable solution. The technologies for the near, medium, and long terms should be forward compatible so that the technology at any one stage can be upgraded to the better version. In planning efforts, it is wise to have a balanced portfolio with a combination of near-, medium-, and long-term technologies. Guarantees of near-term improvements before the next election will win over political decision makers and ensure that they support long-term technologies.

Clearly, the technologies for the near, medium, and long terms should be the most appropriate or best technologies for each period and should be chosen through a 'natural selection' process of competition. In other words, there should be a transition from the most appropriate technology for the near term to the 'best' technology available in the medium term, and then to the 'best' technology for the long term. This process should involve technological leapfrogging, i.e., the historical path of technological evolution is replaced by leapfrogging to the best technology for the next period. This technological leapfrogging approach is fundamentally different from the so-called 'energy ladder', according to which there is a climb from the technology corresponding to one step of the ladder to that corresponding to the next higher step. For example, in the case of cooking, the climb (with increasing income) is from fuelwood to charcoal to kerosene to LPG/electricity. But the energy ladder concept describes past and present behaviour of consumers. In contrast, technological leapfrogging is a normative prescription for future behaviour. The recommendation here is that rural areas not replicate the energy ladder behaviour of the past and present but adopt a technological leapfrogging approach. In Brazil, the introduction of LPG almost completely eliminated the use of fuelwood for cooking (Box 4-1).

Specific Technology Options

The current emphasis with regard to electricity as a convenient energy carrier is on grid electricity. However, due to the problems of supplying grid electricity to small and scattered loads, decentralised generation of electricity is increasingly attractive. Where appropriate, decentralised generation from the intermittent sources of wind and/or small hydro, solar photovoltaics, and solar-thermal sources all have roles to play. The exciting developments are the availability of ~100 kilowatt micro-turbines and ~ 10 megawatt biomass-integrated gasifier combined cycle (IGCC) turbines.

Biomass-based generation of fuels to run fuel cells is an attractive long-term option, particularly because it may be possible to generate surplus base-load power that can be exported from rural areas to urban metropolises. At present, the predominant fuel in rural areas is biomass, particularly fuelwood and agricultural crop

Box 4-1
Liquefied Petroleum Gas in Brazil

Liquefied petroleum gas (LPG) was introduced in Brazil in 1937, when a private entrepreneur started to sell bottles from a stock of a few thousand made available by a German company. In order to promote the use of the new fuel, this private entrepreneur also marketed cooking stoves. After World War II, the business expanded and several multinationals began to import LPG in special ships and bottle it locally. In 1955, PETROBRAS, the national oil company, gained a monopoly of production and imports of LPG. From 1975 on, PETROBAS subsidised LPG through higher gasoline and diesel prices, and the market expanded extraordinarily. While international prices of LPG were US$400 dollars per ton (or higher), prices in Brazil where kept to around US$200 per ton, benefiting millions of people.

In 1999, 97.4 percent of all households in Brazil were equipped with LPG stoves. Approximately 6.5 million 13-kilogram bottles were sold every month, generating 300,000 jobs. Ten thousand trucks were used for distribution. Total consumption was 6.8 million tons per year, of which 2.8 million were imported.

The introduction of LPG for cooking purposes in Brazil has almost completely eliminated the use of fuelwood for cooking. One can estimate that this shift in fuels has avoided the deforestation of one million hectares of forest per year.

Among developing countries, Brazil ranks seventh in per capita consumption of LPG, at approximately 40 kg/capita/year. China, India, Indonesia, and Pakistan consume less than 10 kg/capita/year. In Africa, with the exception of Tunisia and Algeria, average consumption is less than 1 kg/capita/year.

residues. A switch to stoves and furnaces fueled with biogas, producer gas, natural gas, and LPG is an obvious next step. But modern LPG-like fuels derived from biomass, so-called biofuels – syngas in general and dimethyl ether (DME) in particular – may be the medium- and long-term answer.

It is important not to be locked into thinking separately about electricity generation and heating. The cogeneration of electricity and process heat is a well-known, attractive option, particularly when heat can be utilised close to the equipment generating the electricity. Decentralised electricity generation facilitates this combined production of heat and power. It is even possible to go one step further with so-called ‘tri-generation’ systems that combine the production of heat, power, and liquid fuels (synthetic LPG) in Fischer-Tropsch reactors and biomass IGCC turbines (≈ 10 MW).[3]

In the case of cooking, the transition must be made from today’s inefficient, unhealthy stoves using arduously gathered fuelwood, first to improved woodstoves, then to gas-fueled stoves, and then to clean, efficient, convenient stoves operating on electricity or on gaseous biomass-based biofuels. Catalytic burners may also have a place.

The provision of safe water is a crucial task that yields an enormous payoff in terms of improved health. But it invariably requires inputs of energy to go from surface water (often contaminated) to 'safe' ground water lifted from tubewells, to filtered or UV-filtration or treated water, to safe piped water.

With roughly 60 to 70 percent of rural households having no electricity connections and therefore forced to depend on lamps burning plant oils or kerosene, the way forward is electric incandescent bulbs that are replaced as rapidly as possible with fluorescent tubelights and compact fluorescent lamps.

Radical improvements in the quality of life often depend on replacing human and animal power with motive power based on electric motors and engines driven by the combustion of fuels. Today, fossil fuels are conventional sources for engines, but in the future motive power will come primarily from biomass-derived fuels and hydrogen. At the same time, much more efficient motors should be installed.

The plight of women is very much connected with the enormous amounts of arduous physical labour required for basic household chores. A key objective of rural energy must involve reducing the amount and the difficulty of this work. Immediate to long-term improvements can come first from simple electrical appliances and then progress to efficient and then super-efficient appliances. Box 4-2 shows one way in which women are both providing energy services and benefiting from increased incomes.

Rural industries such as pottery and metalworking are currently based on process heat derived from fuelwood and/or other biomass sources such as sugarcane bagasse. Future developments have to be based on electric furnaces, cogenerated heat, producer-gas and natural-gas-fueled furnaces, and solar thermal and induction furnaces. The long-term future will perhaps belong to furnaces based on biomass-derived fuels.

Rural transport particularly within villages and from house to farm and vice versa is today based overwhelmingly on animal-drawn vehicles and human-powered bicycles. Mechanisation, however, is making inroads with vehicles fueled with petroleum products such as gasoline and diesel. Natural-gas-fueled vehicles are bound to play a part as well. Over the medium term, vehicles can be run on biomass-derived fuels such as producer gas, methanol, and/or ethanol, and over the long term, fuel-cell-driven vehicles are the option. The technological sources and devices for the near, medium, and long term are summarised in Table 4-1.

Box 4-2
The Multifunctional Platform Approach: Creating Opportunities for Growth and Empowerment of the Poor

The multifunctional platform project, implemented by UNDP and the United Nations Industrial Development Organisation (UNIDO) in Mali and at a pilot stage in Senegal, Burkina Faso, and Guinea, seeks to reduce rural poverty in general and that of rural women in particular, while creating income-generating opportunities through provision of affordable energy services. To date, about 220 platforms are operational in Mali, where the project intends to install platforms in 450 villages serving about 10 percent of the rural population.

The multifunctional platform has a simple diesel engine that can power different tools, such as a cereal mill, husker, and/or battery charger. The engine can also generate electricity for lighting and refrigeration and to pump water. The advantages of the engine are its simplicity and multiple uses. With its many functions, it can be used for a variety of services that can generate incomes for the group operating the platform. Because it is a very simple machine, its installation and maintenance can all be handled by local artisans and spare parts are readily available across West Africa.

Installation of a platform is demand-driven. A duly registered women´s association has to request it, with the active support of the village community. But before a platform is installed, a social, economic, and technical feasibility study is undertaken that provides the women's association as well as the whole community with information to make an informed purchasing decision, identifies potential partners, and establishes base line indicators against which platform results as well as development impacts at the village level can be monitored. After initial literacy training, the association elects a Women Management Committee, whose members are then trained in managerial and entrepreneurial skills to ensure the technical and economic viability of the platform.

At an estimated cost of US$4,000 for engine, rice de-huller, stone mill, battery charger, and housing for the platform, the platform is comparatively cheap to buy, install, maintain, and replace. Between 40 and 50 percent of the cost is financed by the women's association, often with financial support from the rest of the community; a one-time subsidy of approximately US$2,500 is provided by the project. The project informs beneficiaries of existing financial and management support facilities and facilitates access to credit in order to finance the platform. Depreciation and variable costs (maintenance, salaries of female operators, etc.) are borne entirely by the Women Management Committee. Village case studies clearly indicate that the platform has positive cash flows from the first day after installation.

In each village, around 800 clients – mostly women – buy energy services from the platform, and studies show strikingly positive impacts. In Mali, for example, the project increased annual income per participating woman from about US$40 to US$100 and freed up two to six hours of her time per day (depending on the services of the platform). The 'invisible' time and energy spent on repetitive and tedious work is made visible as women re-organise their allocation of time and as they gain social as well as economic recognition for the work they do. The introduction of a platform in a village has also resulted in higher levels of schooling for girls.

The Challenges of Scaling Up

The experiences of the project show that multifunctional platforms can serve as a basic rural infrastructure to develop the rural economy and to mobilise necessary local capital, with limited assistance from outside.

In order to replicate the platform approach, appropriate measures should focus on establishing conditions for small and informal enterprises to be an engine for growth and rural development. Creating such conditions is an involved process and poses a significant challenge for scale-up. Often, there is no clear policy and institutional framework for decentralised energy management for rural areas. As such, strengthened coordination among public institutions at both central and decentralised levels is needed to integrate the platform approach into existing public and private institutions. Expansion of a decentralised approach depends upon local rural industrial markets, which are narrow, and the rural technical skill to develop and implement a well-designed market strategy, which is very weak. Addressing the capacity development needs of rural communities and rural entrepreneurs must be an essential component of policy measures to promote the platform approach.

As the Malian experience has shown, linking micro-scale experiences with policy formulation at the macro level presents yet another challenge. How a focus on the users of energy services for multiple ends can be a practical engine of synergy for cross-sectoral policy coordination is poorly understood and advocated. For example, macroeconomic analyses that make the link between poverty reduction and economic growth do not sufficiently count and analyse data on the informal sector. Thus the significant prospects that poor people, particularly rural women, represent for growth and poverty reduction tend to get missed. Platform initiatives can be an effective mechanism to collect and analyse social and economic data at the village level that can be aggregated to make their collective contributions to the national economy more visible. An intervention like the multifunctional platform can create ways to connect a well-designed community level intervention to the formulation of national policy and strategies, such as poverty reduction strategies, which reflect concerns of the poor. This is an important step for scaling-up rural energy development.

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Sources: Brew-Hammond, A., and A. Croles-Rees, *Multifunctional Platforms in Africa: A Forward-looking Review* (New York: UNDP, 2001); and Burn, N., M. Takada, and L. Coche, *Concept Paper for the Expanded MFP Project in Africa* (New York: UNDP and UNIDO, 2000).

TABLE 4-1: ENERGY SOURCES AND DEVICES FOR THE NEAR, MEDIUM AND LONG TERM

SOURCE	PRESENT	NEAR TERM	MEDIUM TERM	LONG TERM
Electricity	Grid or no electricity	Biomass-based generation Internal combustion engines coupled to generators	Biomass-based generation through micro-turbines and integrated gasifier combined cycle turbines (IGCC) PV/Wind/Small hydro/Solar Thermal	Fuel cells for baseload power
Fuels	Wood/Charcoal/ Dung/Crop residues	NG/LPG/ Producer Gas/ Biogas	LPG/Biofuels/ Syngas/DME	Biofuels
Cogeneration (combined heat and power)		Internal combustion engines Turbines	Micro-turbines and integrated gasifier combined cycle turbines	
TASK	**PRESENT**	**NEAR TERM**	**MEDIUM TERM**	**LONG TERM**
Cooking	Woodstoves	Improved woodstoves/ LPG stoves	LPG/Biogas/ Producer Gas/ NG/DME stoves	Gaseous biofueled stoves/ Electric stoves/ Catalytic burners
Safe Water	Surface/ Tubewell water	Filtered/treated water/UV filtration	Safe piped/treated water/(De)centralised water treatment	Ultra safe piped/ Treated water
Lighting	Oil/Kerosene lamps	Electric lights	Fluorescent/ Compact fluorescent lamps	Fluorescent/ Compact fluorescent lamps
Motive Power	Human/Animal powered devices	Internal combustion engines/ Electric motors	Biofueled prime movers/ Improved motors	Biofueled prime movers/ Improved motors/ Fuel Cells
Appliances		Electric appliances	Efficient appliances	Super-efficient appliances
Process Heat	Wood/Biomass	Electric furnaces/ Cogeneration/ Producer gas/ Natural-gas-fueled or Solar thermal furnaces	Induction furnaces/ Biomass-fueled or Solar thermal furnaces	Biofuels/Solar thermal furnaces
Transport	Animal-drawn vehicles/Human-powered bicycles	Petroleum/ Natural gas-fueled vehicles	Biomass-fueled vehicles	Fuel-cell driven vehicles

Note: Thanks are due to Robert Williams for help in the finalising this table.

Policies that Promote Rural Energy Strategies

Policies to implement the strategies outlined are needed in the following areas.

- A fundamentally important issue concerns the choice of technology. In a command-and-control set-up, technologies are chosen in a top-down manner by government. In effect, this means that the choice is made by bureaucrats. Unfortunately, such choices are often notoriously defective. One has only to recall the breeder reactor programmes of the United States, France, and Japan, or the Super Sonic Transport (SST) plane. The other option is to allow the market to make the choice through a process of competition. Though the market option is attractive, it is only effective when there is a level playing field for the various contending technologies. This means that deliberate policies are needed to ensure that there is a *level playing field for centralised supply and decentralised village-level supply and for supply expansion and end-use efficiency improvement*. The problem is that yet-to-mature emerging rural energy technologies must not be compared on the basis of their current costs with mature conventional technologies. The place of emerging technologies must be determined on the basis of their future costs resulting from technological advances and organisational learning.

- Policies must promote *household-level supply* of energy when the cost of a household-level system is less than the per-household cost of a community system plus the distribution cost. They must advance community-based supply of energy sources when the cost of sources for N households (i.e., the cost of generation) plus the cost of the distribution network is less (i.e., more cost-effective) than the cost of N household-level sources. But there should also be policies to encourage *'centralised' multi-community supply* of energy sources if the generation plus distribution is more cost-effective than community-level sources.

- Policies are required to promote *integrated resource planning* in order to identify least-cost mixes of sources and associated devices.

- Notwithstanding the importance of the cost criterion for the choice of technology, there are other crucial sustainable development criteria as well. In particular, a technology has to be accepted by society for it to be socially sustainable. This means that there has to be social participation in the choice of technology. Special policies are required to ensure that the *process of technology choice is transparent and democratic*. In this process, whatever criteria can be quantified must be quantified. And criteria that cannot be quantified today should, as an interim measure, be represented with traffic-light colours – green for 'acceptable', red for 'not acceptable', and amber for 'uncertain' – while setting in motion a process to develop a method of quantifying the criteria.[4]

- Policies are needed to promote the development and dissemination of technologies that improve HDI directly (cooking, safe water, home electrification for lighting, space conditioning for comfort, etc.) as well as technologies that improve HDI indirectly via income generation (stationary and mobile motive power, process heating, etc.).

- Policies are necessary *for near-term, medium-term, and long-term time-horizons*. Most urgent is the development and dissemination of technologies that will immediately improve energy services in order to provide a better quality of life for the rural poor.

- Most rural energy technologies (stoves, windmills, biogas plants, wood gasifiers, etc.) have evolved through several generations. The first generation of unsuccessful devices was often the result of the enthusiasm of unqualified amateurs. The second generation of successful prototypes emerged from the creative efforts of competent technologists. The third generation involved the conversion of prototypes into products in the economy, i.e., commercialisation for large-scale dissemination. This third generation required management inputs. Hence, for each rural energy system, for example, producer-gas-based electricity generation, it is vital to have an entire *implementation package of hardware plus 'software'*.[d] Such packages must consist of the technology, economics, financing, management, training, institutions, etc., necessary for the dissemination of that system. Unfortunately, far too often, crucial elements (for example, institutional requirements) are missing in the dissemination programmes, leading to failures. Hence, policies to encourage the preparation of implementation packages are imperative.

- Unlike conventional energy sources/end-use technologies, most new rural energy technologies are in the process of maturing. In particular, their costs are declining because of technological advances and organisational learning. Hence, it is important to have policies that actively promote *technological advances and organisational learning*.

- If they are used as a policy instrument, *subsidies must be time-bound* with a sunset clause and they must promote technological advances and organisational learning. Above all, subsidies must not be a permanent crutch inhibiting the advancement of the technology.[e]

- The establishment and operation of rural energy systems should lead to *local capacity building* in the matter of hardware (technology) and 'software' (particularly management). Policies must be put in place to promote such local capacity building at the rural level, and special attention must be given

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[d] 'Software' refers to the instructions, procedures, knowledge, etc., necessary to utilise the hardware.
[e] The consensus particularly among solar water heater manufacturers in India is that the subsidies provided by the Ministry of Non-Conventional Energy Sources hindered the development of solar water heaters and in particular interfered with cost reduction. Fortunately, these subsidies have been withdrawn.

to operation and maintenance know-how as distinct from construction and design know-how.

- It is vital that policies include a *key role for women* as users, operators, and entrepreneurs in rural energy systems.
- Policies that enable and ensure *people's participation* (in particular for the supply of resources and payment for services) as households and/or as a community are imperative.
- Policies are crucial to arrange/enable *financing* (through leasing, loans, etc.) for households and communities so that unacceptably high initial capital costs are converted into manageable operating costs.
- Policies are needed to encourage and support effective, democratic, and transparent *institutional arrangements at the rural level* to monitor energy systems and maintain clear, transparent records and accounts.
- In view of the shortcomings of government implementation, the strengths of entrepreneurship and the market mechanism as well as the advantages of local community action have to be exploited for operations independent of the government. Nevertheless, government involvement in rural energy systems is essential to provide an enabling environment. Above all, parallel operations by government must not compete with rural energy systems.[f] Thus policies to ensure *synergistic government support* for individual and/or community operation of rural energy systems are vital.
- Policies are required to promote the *establishment of new energy enterprise(s)* if existing institutions such as local-level bodies cannot discharge the new responsibilities. Policies must also encourage financial institutions/banks/donors to take on new tasks.

Rural Energy and Improved Quality of Life

If rural energy strategies are oriented towards the goal of sustainable rural development in the manner outlined above, and the associated policies are implemented successfully, they will have implications for other pressing social problems. Above all, they will result in improved quality of life and HDI. They will help to alleviate poverty, and will dramatically improve the position of women. The life of children will also be improved. The rural environment and the health of rural inhabitants will take a turn for the better. In the long run, there will be a positive impact on population growth. Thus a focus on rural energy will have a synergistic effect on an array of major social problems.

[f] Just when Rural Energy and Water Supply Utilities (REWSUs) in Karnataka State in South India were establishing and operating drinking water schemes based on households paying for piped water to homes, the Karnataka government started implementing a World Bank-financed rural water supply scheme to supply 'free' water in an obviously unsustainable manner.

Conclusions

Strategies for rural energy that would advance the goal of sustainable rural development are the reduction of arduous human labour, the modernisation of biomass, the transformation of cooking, the provision of safe water for domestic requirements, the electrification of all homes, and the provision of energy for income-generating activities.

Dramatic improvements in the quality of life (safe, clean, and efficient cooking and home electrification) can be achieved with very small investments of energy of about 100 watts/capita.

The real or opportunity costs of traditional practices are an important benchmark because invariably they define the maximum amount that the household is willing to spend. Thus, the operating costs of traditional devices are a sort of upper bound for the costs of an alternative technology. The window of technological opportunity is upper-bounded by the maximum possible household expenditure on energy, but technological advances can widen the window of opportunity.

The conversion of capital costs into affordable operating costs requires investments from financial institutions. However, many of the new tasks are ones to which these institutions are not accustomed and therefore they may have to go through a learning process. New energy enterprise(s) may also have to be developed and established if existing institutions such as local-level bodies cannot discharge the new responsibilities.

The identification of technological options for sources/devices depends very much on the time horizon. Starting from the present technology (the initial condition), there is a necessity of three types of technology for each energy-utilising task – a near-term technology, a medium-term technology, and a long-term technology that should provide an ideal sustainable solution.

Instead of rural areas replicating the energy ladder behaviour of the past and present, they must adopt an approach of technological leapfrogging (a normative prescription of future behaviour) to the 'best' technology for the next period.

To implement rural energy strategies, it is necessary to have policies to ensure that there is a level playing field for centralised supply and decentralised village-level supply and for supply expansion and end-use efficiency improvement so that the market can make the choice through a process of competition; to promote household-level supply, community-based supply of energy sources, and 'centralised' multi-community supply of sources (whichever is appropriate); to promote integrated resource planning in order to identify least-cost mixes of sources and associated devices; to ensure that the process of technology choice is transparent and democratic; to develop and disseminate technologies for direct HDI improvement and indirect HDI improvement via income generation and for the immediate-term, medium-term, and long-term time-horizons; to develop hardware plus 'software' implementation packages for rural energy systems; to promote technological advances and organisational learning; to ensure that subsidies are not a permanent crutch inhibiting the advancement of the technology; to lead to local capacity building in the matter of hardware (technology) and 'software' (particularly management); to include a key role for women as users, operators, and entrepreneurs in rural energy systems; to enable and ensure people´s participation as households and/or as a community; to arrange/enable financing for households and communities; to lead to democratic and transparent institutional arrangements at the rural level to monitor rural energy systems; to ensure synergistic government support for individual and/or community operation of rural energy systems; to promote new energy enterprise(s) to be established if existing institutions such as local-level bodies cannot discharge the new responsibilities, and to encourage financial institutions/banks/donors have to take on new tasks.

Annex A
Dissemination of Photovoltaic Solar Home Systems in Rural India

India's population according to the 1991 census was 846 million. The rural population was 74.3 percent, or 623 million, which at 5.5 persons per household corresponds to 114 million households. Of these households, 69 percent, or 78.6 million, were not electrified. The initial cost of a four-light, 37-watts photovoltaic solar home system (PV SHS) in 1999 was about US$430 (Rs 18,500 @ Rs 43/US$), for which financing from a bank could be obtained at 12 percent interest over a five-year period. This corresponded, after a down payment of 15 percent (US$64.50), to a household expenditure of US$101.45 (Rs 4,362) per year or US$8.45 (Rs 364) per month.

On average, energy accounts for about 7.5 percent of household expenditures. On the (probably overly optimistic) assumption that this could be doubled, then 15 percent of monthly household expenditures is the upper limit to what a household can spend on energy. The monthly cost of US$8.45 for a PV SHS translates, at 15 percent, to a required household income of US$56.36 (Rs 2,423) per month. The income distribution pattern in India is such that only about 7 percent of households have this level of income to afford a PV SHS. Assuming that only half of households that can afford a PV SHS are prepared to switch to purchase one, much less than 5 percent of rural households constitute the market for such systems.

The potential penetration is greater with the smaller systems. The two-light, 20-watt PV SHS costs about US$267.50 (Rs 11,500) and can be obtained with the same financing terms as the four-light system. This would involve a down payment of

US$40.12 (Rs 1,725) and monthly payments of US$5.26 (Rs.226), requiring an income of about US$35.00 (Rs.1,506) per month – available to about 17 percent of the households. The one-light, 10-watts PV SHS costs about US$128.00 (Rs.5,500) and implies (with the same financing terms) a down payment of about US$19.20 (Rs.825) and monthly payments of about US$2.50 (Rs.108), requiring a monthly income of about US$16.75 (Rs.720) – available to about 75 percent of households.

Thus the two- and four-light systems can only be afforded by the richest rural households, constituting 17 and 7 percent of the population, respectively.[g] Even the cheapest one-light PV SHS is beyond the means of the poorest 25 percent of the rural population.

Since PV SHSs are inaccessible to the rural poor, the question arises: are they *elitist* energy sources/devices? If the purpose of PV SHS is not merely to improve the quality of life of the household, but to illuminate activities that augment income, then the elitist characterisation may not be applicable. For example, a one-light PV SHS might permit a tribal household to weave two extra baskets per evening, earning US$0.12 (Rs.5) per basket and therefore (after paying for materials) about US$5.80 (Rs.250) per month; the income generated by the PV SHS would more than pay for the investment in the light. Similarly, light might give a mobile vegetable vendor two extra hours of sales and thus increased income. These examples show that there are non-elitist niche markets for PV SHS.[5]

[g] The factors limiting penetration of PV SHS systems to the richest segments of the population can be found even in the lending programmes of the Grameen Bank of Bangladesh, which is world famous for its success in extending micro-credit to the poor. Bangladesh's projected population for 1996 was 123.6 millions. The rural population was 79.9 percent, or 98.8 million people, which at 5.6 persons per household corresponds to 17.6 million households. Of these households, 86 percent, i.e., 15.2 million households, were not electrified. The initial cost of a PV SHS is Taka 9,200 (Taka 45.5 ≈ US$1), for which Grameen intends to provide financing at 8 percent interest over a two-year period after a 25 percent down payment. This corresponds to a household expenditure of Taka 3,867 per year or Taka 323 per month. On average, a household spends about 5.5 percent of its expenditure on energy. If, to be liberal, this is doubled, then 10.9 percent of its monthly expenditure is the upper limit to what a household can spend on energy. The monthly expenditure on a PV SHS of Taka 323 per month translates at 10.9 to a household income of Taka 2,952 per month. About 46.8 percent of households in Bangladesh have the income required to afford a PV SHS. Assuming that only half of those households that can afford it are prepared to switch to PV SHS, it appears that less than a quarter (23.4 percent) of rural households constitute the market for such systems in Bangladesh.

For Further Reading

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5 Thanks are due to Dr. Harish Hande, SELCO, for these real-life examples.

5 The Innovation Chain: Policies to Promote Energy Innovations

WIM C. TURKENBURG

Technological innovation is crucial to the re-shaping of energy systems in ways that encourage sustainable development, a point supported by considerable analysis presented in this volume and the World Energy Assessment.[1] But the development and dissemination of clean, safe, sustainable, and affordable energy technologies is not occurring fast enough or widely enough to realise the goal of sustainable development. What is needed are policies to strengthen and focus the innovation process to support sustainability.

Most ongoing innovative activity is for incremental improvements in technologies already established in the market, i.e., *technology optimisation*. Achieving a more sustainable energy future, however, will require *function optimisation* – that is, it will require determining what energy functions are asked for and how the provision of these functions can be optimised while taking into account the need for sustainability. This in turn will require development of new (energy) systems, optimisation of existing systems, as well as development and implementation of new technologies.

Meeting the demands of sustainability will require major improvements in the efficiency of energy use, a much higher reliance on renewable energy technologies, the application of cleaner fossil fuel technologies, and advanced nuclear technologies if they can be applied in a sustainable and publicly acceptable manner. While much can be accomplished through wider deployment of commercial technologies, new technology development is also needed.

New technological energy options hold great promise, but their development and dissemination is not occurring fast enough or on a large enough scale. Acceleration of the energy innovation process should be achieved through all effective means, including appropriate public policies. Where there has been substantial progress with radically new technologies, it has mainly been based on past government-supported activities for which support has subsequently declined.[2]

Without policy changes, cost differentials may favour conventional fuels and technologies for years to come. Yet the physical resources and technical opportunities are available – or could become available – to meet expanded needs for energy services in ways that support sustainable development.

This chapter first discusses some general features of the innovation chain. It is indicated that the process leading from invention to wide scale dissemination of new products is not linear. Despite the overlap in various phases of the innovation process, it is useful to examine the different stages of the innovation chain: research and development, demonstration, and diffusion. Each stage has distinct requirements, faces specific barriers, and requires different policy approaches to overcome these barriers.

The role of government in innovation is discussed. Rationales for governmental participation or interventions in the innovation process are presented. Different approaches to technology development are indicated, each of them associated with a specific government intervention strategy. Also, a governmental strategy for energy innovation is formulated.

Next, public and private sector spending on energy technology innovation are analysed. The spending on energy RD&D in the period 1975–2000 are investigated. Then the need for early investments in new energy technology deployment activities is discussed to 'buy down' the costs of these technologies along their experience curves to levels at which the technologies can be widely competitive.

Specific attention is given to the need for closer collaboration between industrialised and developing countries to enhance technological innovation for energy efficiency, renewables, and cleaner use of fossil fuels in the developing countries. Developing countries have the opportunity to leapfrog directly to modern, cleaner, and more energy-efficient end-use and supply technologies. New policy instruments are needed to stimulate such a development, based on a participatory development approach. Also pathways for South-South transfer of technologies are discussed.

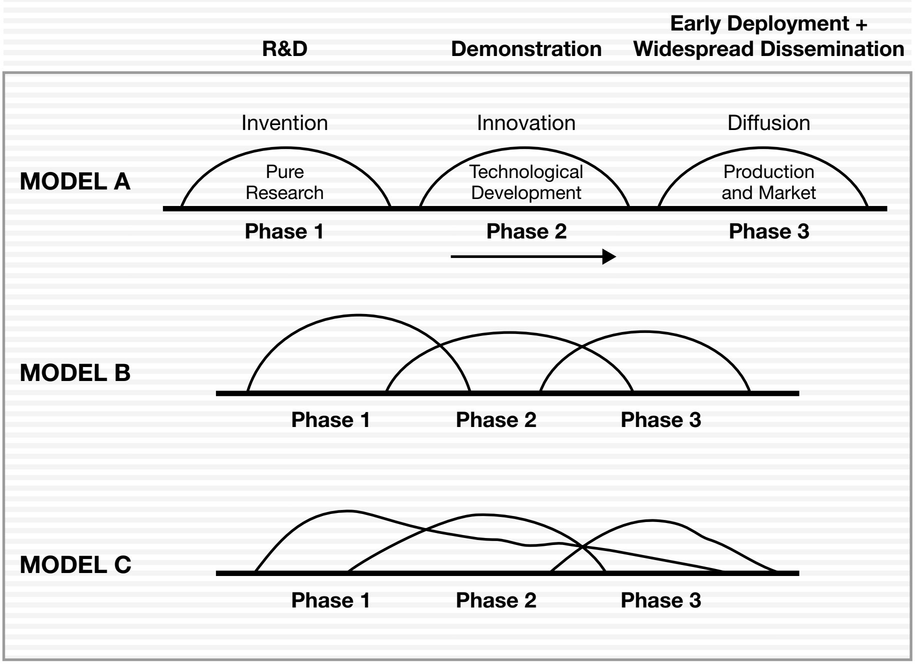
Finally, a summary is given of policy instruments that can be applied to enhance energy innovation. Three groups of instruments are discussed: to steer or stimulate RD&D, to foster the deployment and dissemination of sustainable energy technologies, and to remove imperfections in the (national) system of energy technology innovation.

The Innovation Chain

A proven technology is the result of earlier invention and innovation that has become established and is widely adopted and accepted. An invention is the initial idea, sketch, or model for a new or substantially improved device, product, or process. An innovation is accomplished only with the first commercial transaction involving the new product, process, or device. Diffusion refers to the initial testing and then wide spread adoption or implementation of an innovative technology.

The innovation process consists of several developments taking place both simultaneously and sequentially. There is a general misconception that the process leading from invention to a new product is linear, that it takes place without any feedback occurring among the different stages. In practice, technologies are continuously adapted and improved to better fit conditions and requirements, and the distinction between innovation and dissemination is often hard to draw. Figure 5-1 illustrates various models of technological development. Model A is linear, depicting the misconception that pure research leads to technological development and then to products that open new markets or conquer existing ones. This approach to science and development served as the blueprint for the U.S. National Science Foundation

FIGURE 5-1: THREE MODELS FOR THE RELATIONSHIP BETWEEN SCIENCE AND DEVELOPMENT



when it was established; it was widely copied throughout the world. But Model A ignores the interaction that is needed for the process to work. In moving from pure research to technological development and then to the production and marketing of new products, unanticipated problems arise that require re-examination and adaptation at the earlier stages.

Models B and C more accurately depict how technological development actually takes place today in various countries. Model B shows some overlap among the phases, and Model C shows nearly complete overlap. In both models, practical needs – that is, demand – influence supply, namely the type of pure research that is conducted. For example, after solid-state devices such as transistors made possible the expansion of switch boarding in telephone services, industrial laboratories such as Bell Laboratories lavishly financed solid-state physics.

To develop and put into widespread use new technologies, developing countries should emulate models B and C. In many developing countries, however, government goals and the 'demand side' pull are lacking. As a result, universities and research centres have become isolated ivory towers, more connected to research centres in Europe or the United States than to the obvious needs of industry, agriculture, and education in their own countries. Science and technology budgets receive little support from the private sector and instead depend on the national treasury.

Despite the overlap in various phases of the innovation process, it is useful to examine the individual stages that make up the process from beginning to end. The energy innovation chain can be broken down into three stages: research and development (R&D), demonstration (D), and diffusion (D), which includes both early deployment and widespread dissemination of the new technologies. Each stage has distinct requirements, faces specific barriers, and requires different policy approaches to overcoming those barriers (Table 5-1). For instance, government support (in the form of funding, incentives, regulations, policies, etc.) is often particularly crucial in the research and development stage, especially for long-term research for radically new technologies.

Before they can reach commercial readiness, new technologies, processes, building designs, and infrastructure need several years to decades (depending on the technology) for research, development, and demonstration (RD&D). And once they become commercially ready, these technologies typically require decades to achieve major markets shares.[3] This underscores the need for accelerated progress along the innovation chain for promising technologies to achieve sustainable development within one or two generations.

Demonstration plants and early production units are often much more costly per unit of installed capacity than plants based on existing technology. However, the unit cost of manufactured goods tends to fall with cumulative production experience – a relationship called 'an experience curve' when it accounts for all production costs across an industry. Early investments can 'buy down' the costs of new technologies

TABLE 5-1: THE ENERGY INNOVATION CHAIN: BARRIERS AND POLICY OPTIONS

	Research and Development (laboratory)	**Demonstration** (pilot projects)	**Diffusion**	
			Early Deployment (technology cost buy-down)	**Widespread Dissemination** (overcoming institutional barriers and increasing investment)
Key Barriers	• Governments consider R&D funding problematic • Private firms cannot appropriate full benefits of their R&D investments	• Governments consider allocating funds for demonstration projects difficult • Difficult for private sector to capture benefits • Technological risks • High capital costs	• Financing for incremental cost reduction (which can be substantial) • Uncertainties relating to potential for cost reduction • Environmental and other social costs not fully internalised	• Weaknesses in investment, savings, and legal institutions and processes • Subsidies to conventional technologies and lack of competition • Prices for competing technologies exclude externalities • Weaknesses in retail supply, financing, and service • Lack of information for consumers and inertia • Environmental and other social costs not fully internalised
Policy Options to Address Barriers	• Formulating research priorities • Direct public funding • Tax incentives • Technology forcing standards • Stimulating networks and collaborative R&D partnerships	• Direct support for demonstration projects • Tax incentives • Low-cost or guaranteed loans • Temporary price guarantees for energy products of demonstration projects	• Temporary subsidies • Tax incentives • Government procurement • Voluntary agreements • Favourable pay-back tariffs • Competitive market transformation initiatives	• Phasing out subsidies to established energy technologies • Measures to promote competition • Full costing of externalities in energy prices • 'Green' labelling and marketing • Concessions and other market-aggregating mechanism • Innovative retail financing and consumer credit schemes • Clean Development Mechanism

Source: Adapted from M. Jefferson, 'Energy Policies for Sustainable Development', in United Nations Development Programme (UNDP), United Nations Department of Economic and Social Affairs (UNDESA), World Energy Council (WEC), *World Energy Assessment: Energy and the Challenge of Sustainability*, J. Goldemberg (Chairman Editorial Board), (New York: UNDP, 2000). Table 12.2.

along their experience curves to levels where the cost of new technologies may be competitive with existing technologies. Strategies are required to overcome policy, institutional, and end-user financial barriers to the wide dissemination of new sustainable energy technologies that are both proven and cost-competitive.[4]

RD&D capacity is much larger in industrialised countries than in developing countries, and thus technologies with worldwide application are more likely to occur there. Industrialised countries also have large enough markets to buy down front-end costs. However, RD&D for some of the technologies of greatest interest to developing countries is likely to be under-funded in industrialised countries (e.g., decentralised rural electrification), and thus needs to be encouraged through governmental action.

The Role of Government in Innovation

Technological progress plays a central role in the modern economy.[5] It is an important contributor to prosperity and economic growth. It is a crucial element in achieving sustainability and in determining the competitiveness of firms in the market place, nationally and internationally.[6] Firms invest in RD&D to achieve technological advances that allow them to improve productivity, develop new products, create new markets, succeed in competitive markets, and meet environmental and regulatory requirements.

Investments in RD&D tend to pay off handsomely both for individual firms and for society as a whole. The rate of return on RD&D in the U.S. economy has been estimated to be between 20 and 100 percent.[7] Findings from various analyses show the following: 1) the profitability of private investments in RD&D exceeds that of other investments, usually by a substantial margin; 2) private investments in RD&D generally also have significant social benefits and returns; 3) the social and private rates of return of investments in RD&D are significantly higher than the rate normally required for private sector capital investments (typically around 10 percent).

Rationales for Government Participation in RD&D

There are RD&D activities that do not offer enough of an incentive for the private sector, but whose results can yield significant benefit to society as a whole. In these cases, where the market fails, there can be good reasons for government to step in and support RD&D efforts. Therefore, rationales for government participation in RD&D include the following:[8]

- Some kinds of innovations that would lower costs for all consumers – and thus are in society's interest – are not pursued by individual firms because the resulting gains are judged unlikely to be appropriable. Therefore, the firm that does the RD&D may obtain little advantage over competitors who can utilise the results nearly as fast as the first firm but without paying for them (the well-known 'free rider' problem).

- Some kinds of innovations are not pursued by the private sector because they relate to production or preservation of public goods (e.g., the environment) that are not reflected in the profit-and-loss statement of firms.
- RD&D that will take a long time to complete is likely to fall short of the private sector's requirements for a rate of return attractive to investors, even if confidence of success is high.
- RD&D that is costly and has a high risk of failure may exceed the risk threshold of the private sector even though occasional successes can bring very high gains.

During the 1960s and 1970s, the focus for stimulating technology development was on the supply side or 'science push' side. Governments intervened by stimulating investments in RD&D in both private firms and national public research institutes. By the early 1980s, increasing RD&D expenditure was no longer regarded as adequate, and focus shifted to addressing the under-exploitation of the new knowledge and technology available. It was no longer enough simply to generate knowledge; instead the knowledge and innovative technologies needed to be transferred to firms that could actually use them. By the early 1990s, technological development began to be seen as a highly interactive process involving more than increasing the supply or diffusion of knowledge. Government intervention began to focus on stimulating learning and cooperation in an innovative climate, raising awareness, and improving the articulation of demands, apart from creating the conditions that facilitate RD&D activities, technological development, and transfer of knowledge, technologies, and competence.

This trend relates to the systems of innovation approach to be discussed later in this chapter. For policymakers it implies the need to embed innovation policies in a broader socio-economic context and a shift from top-down to network steering. It also implies that governmental innovation policies have to deal not only with the concept of *market failure*, but also with *system imperfections*.[9] Jacobsson and Johnson, in an analysis of the innovation system approach in energy systems, identify the following flaws in the innovation system:[10]

- Potential customers may not be able to articulate their demand and meet the supplier in the market place.
- A new technology may suffer from facing incumbent substitutes that have been able to undergo a process of increasing returns.
- Firms may search only 'locally' to improve their technology, being ignorant of opportunities elsewhere.
- The market may be controlled by dominant incumbents, which means that the selection process may not involve a 'free' choice by customers.

- Firms may not be well connected to other firms with an overlapping technology base, hindering knowledge transfer.
- Firms may be guided by others (i.e., by the network) in the wrong direction or fail to supply one another with the required knowledge.
- Legislation may bias the choice of technology in favour of the 'incumbent' technology.
- The educational system may unduly support current firms and technologies as distinct from potential ones.
- The capital market may not respond 'spontaneously' in response to the need of a new technological system.
- A new technology may suffer from a lack of highly organised actors.

Potential Governmental Intervention Strategies

There are a variety of intervention strategies by which governments can enhance technological development. The selection of a strategy depends on how technological development is perceived. Discussed here are four approaches to technology development, each of them associated with a specific government intervention strategy.[11]

Neoclassical Economic Approach. Mainstream thinking in this approach considers technology as an exogenous factor. At the macro-level, technological development is postulated as a residual of the production function: it is what is left to explain economic growth after the effects of labour and capital have been accounted for. The central assumption in the traditional neo-classical economic view is the existence of competitive equilibrium. Efficient allocation results in optimised welfare. If markets fail, government may intervene to correct this failure. For example, government can correct for under-investments (stimulating RD&D), protect accessibility of knowledge (patent systems), avoid market imperfections (antitrust laws), and avoid information asymmetries (providing information).

Evolutionary Economic Approach. Within this approach, technological development is treated as an endogenous factor. In order to deal with uncertainties, firms tend to innovate along certain familiar and known paths. This can lead to non-optimal outcomes when firms become locked in to a specific set of technologies and assumptions and can no longer respond flexibly to changing circumstances. Government can intervene by generating variation within an entrepreneurial climate that enhances innovation, formulating selection requirements, broadening the selection environment, establishing feedback between variation and selection in niches or nexus, and avoiding lock-in to undesired trajectories.

Industrial Network Approach. Technological development is seen as the result of interaction among various economic actors. Technological development takes place in the realm of economic relationships that belong to 'neither market nor hierarchy'. A firm never innovates in isolation. Actors are embedded in industrial networks. These networks serve as a coordinating mechanism, play an important role in creating and accessing tacit knowledge, and have a constraining and enabling function to important external resources. Government can intervene by building and renewing local knowledge-intensive networks, by stimulating cooperation, and by undertaking some of the actions described under the approaches mentioned above.

Systems of Innovation Approach. Within this approach, technology development is regarded as an iterative learning process characterised by complex feedback mechanisms and relationships among actors in a specific context consisting of science, technology, production, policy, and demand. This approach has a national, regional, or cluster focus towards technology development (in contrast to the firm-based evolutionary economic approach). Technology development is seen as a social process that evolves most successfully in networks with intensive interaction between suppliers and buyers of goods, services, technology, and knowledge, including public knowledge infrastructures such as universities and semi-public research institutes.[12] Government can intervene by: maintaining the institutional knowledge infrastructure of universities and research institutes, stimulating interactive learning among the variety of actors present in the (national or technical) innovation system, monitoring the innovation system by institutional mapping in order to improve the system's overall performance, creating complementary links between public and private actors in order to optimise the use of the knowledge produced, creating and facilitating access to knowledge, and matching the supply and demand for knowledge within the system.

All four approaches share the view that innovative technology cannot be described solely in technical terms. They reject the linear and sequential model of technological development (Model A in Figure 5-1) and refute the suggestion that the technologically optimal solution will result automatically. Instead technology development is an interactive process, involving economic, technical, and social elements, whose outcome is innovative technology.

Government can influence technological development at each stage of the innovation chain. In many countries, government tries to enhance the national capacity for producing, transferring, and exploiting RD&D, knowledge, and innovative technology. The number and nature of applied policy instruments and intervention strategies has changed over time.

Formulating a Governmental Energy Innovation Strategy

The financing of RD&D, the maintenance of a high-value scientific and technological infrastructure, an appropriate education system, and an appealing innovative environment are central tasks of the government. In many countries, this has resulted in a general governmental policy for research, development, and demonstration. Often it also results in RD&D policies directed towards specific subjects of public interest, such as the energy issue.

Major criteria for determining whether government should finance a particular area of energy research are:

- *Is it expected to contribute to achieving a transition to a sustainable energy future?* Determining this requires taking into account aspects like the availability of (national) energy resources, the accessibility of these resources, the national dependence on energy imports, the need to reduce environmental impacts of energy consumption, and the pros and cons of different (new) energy technologies to deliver the demanded energy services.

- *Will it strengthen (national) industries?* Will it help (national) industries compete in national and global markets, while also providing employment to local communities?

- *What is the quality of the research infrastructure in a specific field?* To achieve focus and selectivity in national energy research, it is important to assess how the country's research infrastructure ranks internationally in a specific field. However, there should always be some room for undertaking research in new, unconventional directions that can result in new approaches in the energy field.

A number of additional considerations help to determine *how* energy research funds should be utilised.[13]

- *Limit the number of topics*. It is better to conduct good RD&D on a limited number of issues than on many issues haphazardly. Public funds for energy RD&D should be focused on a limited number of subjects, taking note of the 'critical mass' needed to allow success.

- *Optimise the efficiency of public expenditures*. The record of governments in 'picking the winners' is not good. This suggests that government should pursue a more generic approach at the research stage, and then (in combination with private funding) take a more specific approach at the development and demonstration stage. Since companies tend to focus more on short-term research and development, government should shift attention to more long-term development and demonstration. Demonstrations are needed to test new products, new facilities, and new processes to manufacture a technology and to prove their technical and economic viability. An essential component of demonstration activities is monitoring the performance and evaluating the results, such that lessons can be learned for further developments. The private sector may find it difficult to build demonstration plants for various reasons – high capital requirements, required rates of return, high risk, and difficulties in appropriating the long-term benefits. Thus public participation is needed when clear public benefits can be associated with the technology.

- *Strengthen international cooperation*. For most countries, developing technologies in a purely national context would constitute an inefficient use of public resources. RD&D should be an international activity that addresses concerns of and collaborates with many partners. Strengthening it on a local level requires international cooperation.

- *Enhance the application of knowledge*. Not all research will lead to (costly) demonstration, and not all demonstration will lead to (costly) product development and market application. However, enhancing the diffusion of knowledge may result in better social and industrial use of it. Therefore, apart from RD&D, an important role for government is developing policies that promote the use of technology and innovation in ways that capture the public benefits from RD&D.

Capturing the public benefits from RD&D also requires that modern innovation policies deal with system imperfections. This may require the following roles for government (see Jacobson and Johnson[14]):

- Make sure that there is funding for new knowledge creation and that there are actors willing to do the research.
- Improve linkages in the system so that existing knowledge is widely diffused.
- Help actors to find one another and stimulate the formation of new networks.
- Shape new and strong user-supplier links.
- Be patient in the process of adjusting the institutional set-up in favour of the new technological system, as the time scale involved is probably very long.
- Take note of the need for variety and consistency in the applied policies to support technology diffusion and industry development.
- Be aware of the struggle between proponents of new technologies and incumbents of the old ones.
- Stimulate *prime movers*, as they perform four important tasks: they raise awareness, undertake investments, provide legitimacy, and diffuse the new technology.

Public and Private Sector Spending on Energy Technology Innovation

It is widely held that investment in sustainable energy technology innovation is low in general, and has been declining since the early 1980s. However, even when spending has declined, productivity of the spending may have increased.[15] Nevertheless, there is concern that spending on energy innovation, from both private and public sources, may prove inadequate relative to the challenges confronting the world in the twenty-first century.

It is useful to examine spending trends in terms of the early (research, development, and demonstration) and the later (deployment and dissemination) stages of the innovation chain.

Spending on Energy RD&D

Based on data from the United States, private sector spending for energy research spending is believed to have been low as a share of sales over a long period. In recent years, U.S. utilities appear to have invested just 10 percent as much as U.S. industries overall. But where most major electric utilities and oil and gas companies in industrial countries spend less than 1 percent of sales on RD&D, the main research-oriented firms (such as Asea Brown Boveri, and Siemens) invest eight to thirty times as much. Still, spending on energy RD&D seems low relative to the 7 percent of GDP represented by retail spending on energy in countries that are members of the International Energy Agency.[16]

In several countries – Finland, Germany, and Japan – private sector spending has increased in recent years for renewables, energy efficiency, and advanced cleaner fossil fuel technologies. However, in the same period private sector energy RD&D expenditures in other countries – the United States, Italy, Spain, and the United Kingdom – have declined.

In recent years, eight countries account for about 98 percent of the public expenditures on energy RD&D: Japan, the United States, France, Italy, Canada, the Netherlands, Switzerland, and Germany. Japan and the United States account together for about 80 percent.

After a steep increase in the 1970s related to the oil crises in these years, public expenditure for energy RD&D (see Table 5-2) has been falling steadily in industrial countries, from US$15 billion in 1980 to about US$7 billion in 2000 (figures in US$ 2000). About two-thirds of the decline occurred in the United States. Major declines also happened in Germany, the United Kingdom, and Italy. Public spending on energy RD&D remained stable or increased in Japan, Switzerland, Denmark, and Finland.

Of the US$7 billion spent on RD&D in the year 2000, about 8 percent was on renewables, 6 percent on fossil fuels, 18 percent on energy efficiency, 47 percent on nuclear energy, and 20 percent on other items.

Public spending on energy efficiency was generally higher in the 1990s than in the 1980s. Meanwhile the widespread use of more energy efficient devices and systems has become commonplace, although there are still many institutional and other implementation barriers to be overcome[17], requiring attention by policy makers and RD&D.

Spending on renewables declined after 1980 by about 70 percent, but is fairly stable since 1987. The decline has been much less for biomass and solar photovoltaics. Spending on fossil fuels research declined sharply from US$2.5 billion in 1980 to about US$0.4 billion in 2000. However, public and private spending on coal

TABLE 5-2: REPORTED PUBLIC SECTOR SPENDING ON ENERGY RESEARCH, DEVELOPMENT AND DEMONSTRATION IN IEA COUNTRIES (MILLIONS OF U.S. DOLLAR – 2000 PRICES AND EXCHANGE RATES).

	1975	1980	1985	1990	1995	2000*
Energy conservation	333	954	725	509	1,079	1,269
Fossil fuels	587	2,564	1,510	1,793	952	426
- oil and gas	*139*	*563*	*458*	*354*	*423*	*187*
- coal	*447*	*2,002*	*1,052*	*1,439*	*528*	*239*
Renewable energy	208	1,914	843	563	670	525
- Solar PV	*24*	*383*	*249*	*196*	*235*	*235*
- Other Solar options	*49*	*659*	*154*	*92*	*94*	*57*
- Wind	*7*	*179*	*136*	*88*	*106*	*70*
- Biomass	*6*	*139*	*161*	*79*	*136*	*91*
- Geothermal	*118*	*435*	*130*	*95*	*83*	*53*
- Others	*4*	*120*	*13*	*13*	*15*	*20*
Nuclear energy	5,405	8,015	8,045	5,254	4,498	3,259
- nuclear fission	*4,808*	*6,794*	*6,575*	*4,199*	*4,506*	*2,709*
- nuclear fusion	*597*	*1,221*	*1,469*	*1,055*	*991*	*550*
Power and Storage Technologies	138	426	276	258	320	341
Other technologies / other energy research	893	1,160	787	916	1,104	1,075
Total	**7,563**	**15,034**	**12,185**	**9,294**	**8,622**	**6,966**

* Preliminary figures; complete data not yet available.

Source: IEA, 2002 (see: http://data.iea.org/wds53/wds/eng/main.html)

and natural gas has tended to increase, particularly on clean fuel technologies and modestly on carbon removal and sequestration.

There is little information on energy RD&D spending in developing countries, and with a few exceptions it is likely that spending has been modest.[18]

Spending on Deployment and Dissemination

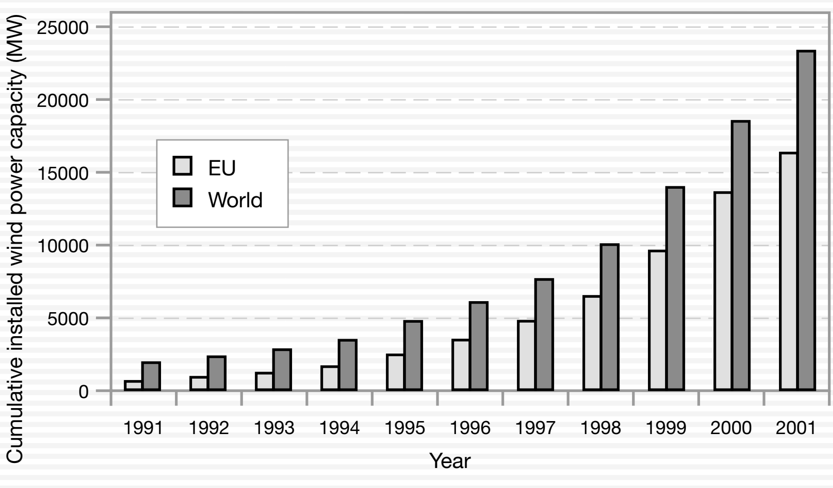
The innovative process requires investment not only in RD&D but also for starting up the market diffusion of new energy technologies. In recent years, more attention has been given to the phase between demonstrations and commercial competitiveness, i.e., to the phase called early deployment in the innovation chain.

For essentially all technologies and production processes, a substantial amount of experience or learning results from their application, which in turn reduces cost. For various products and processes that are in an early implementation state, cost reductions have been observed ranging from 10 to 30 percent each time cumulative production doubles.[19]

This phenomenon – called learning or experience curve – has motivated private firms to use forward pricing.[20] That is, they initially sell products below production cost under the expectation that learning effects will drive cost down and that profits will be generated later. But for many technologies, including renewables, it may be difficult for an individual firm to recover the costs of forward pricing. Here public financial support in combination with other measures can be key to success. In the wind industry in Denmark, a combination of private initiative and public policies, including subsidies, favourable feed-in tariffs, physical planning, and wind turbine certification, has produced a thriving industry with a 50 percent share of the world market. Figure 5-2 shows the growth in the cumulative installed capacity of wind energy converters in recent years, globally and in Europe.

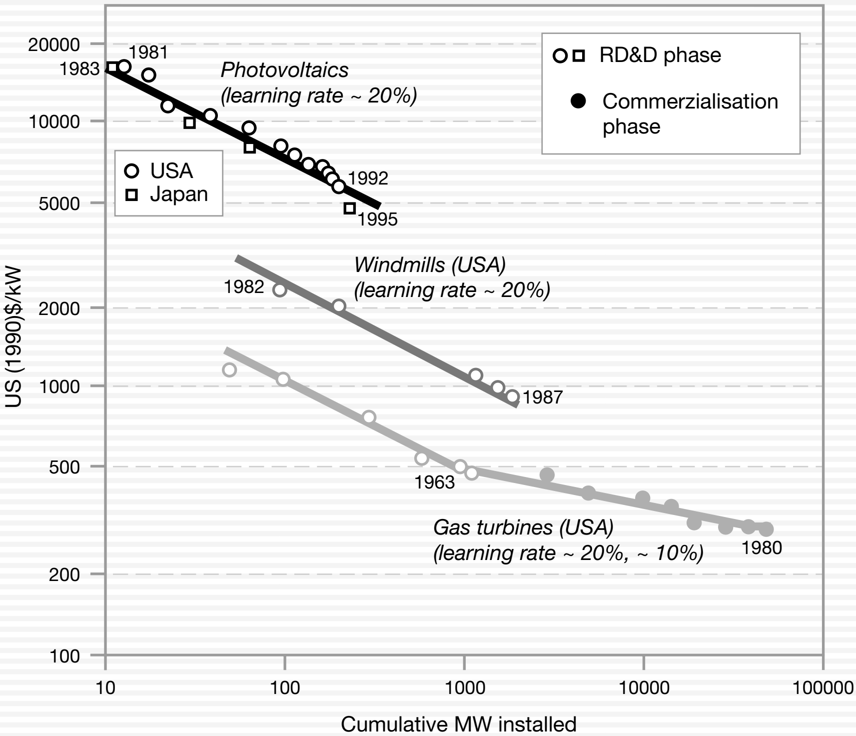
Learning-by-doing generates stocks of tacit and explicit knowledge that drive down costs and thus prices in a manner that is captured by experience curves. Historical learning rates for wind, photovoltaics, and gas turbine energy technology experience curves are indicated in Figure 5-3. The figure gives learning rates of about

FIGURE 5-2: CUMULATIVE INSTALLED CAPACITY OF WIND ENERGY CONVERTERS, GLOBALLY AND IN EUROPE



Source: BTM Consult ApS., Denmark, March 2001 (see: http://www.btm.dk).

FIGURE 5-3: FIRST ESTIMATES OF EXPERIENCE CURVES FOR PHOTOVOLTAICS, WIND GENERATORS, AND GAS TURBINES



Source: N. Nakicenovic, A. Grübler, and A. MacDonald, *Global Energy Perspectives* (Cambridge, UK: Cambridge University Press, 1998).

20 percent for wind turbines as well as solar photovoltaic modules (i.e., panels that convert light into electricity using the photovoltaic effect). More recent studies also show a learning rate of about 20 percent for solar modules. In the case of wind turbines, however, the recent studies, analysing developments on a global level and over a longer time frame (until the year 1997), found the learning rate to be highly uncertain but probably much lower: between 8 and 15 percent.[21] Moreover, to date, the reduction in the wind turbines costs (US$/kW) has been achieved primarily by scaling up the size of the turbine and less by mass production. As wind turbines have a much better performance today than fifteen years ago, the production cost of electricity from wind turbines as a function of cumulative installed capacity has probably come down faster, with a learning rate between 10 and 20 percent.

Experience curves can be used to gain insights about future price trends, although there is no guarantee that historical learning rates will persist. Indeed, Figure 5-3 suggests that the learning rate for gas turbines in the United States probably declined from 20 percent in the early years to about 10 percent as the technology matured. But combining these trend extrapolations with so-called bottom-up engineering analyses to guard against unrealistic cost estimates from blind extrapolations can help clarify future prospects.

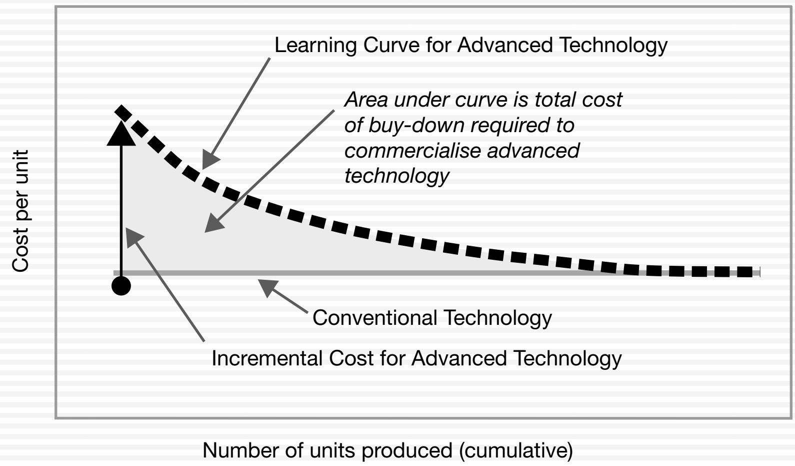
Experience curves indicate that the more rapidly demand grows, the more quickly prices decline. Suppose favourable public policies are adopted that make it possible to sustain an average growth rate of 20 percent per year for wind electric generation throughout the first quarter of the twenty-first century. Under this scenario, installed wind power would grow to about 1,000 gigawatt by 2025, at which time wind power may account for more than 10 percent of world-wide electricity generation. As noted, the historical learning rate for the cost of wind electricity generation may have been between 10 and 20 percent. But even if wind technology is sufficiently mature that the learning rate from now on is only 10 percent, the cost of wind electricity generation under this scenario would fall from a lowest figure of about 0.05 US$/kWh in 2000 to less than 0.04 US$/kWh by 2010 and 0.03 US$/kWh by 2020. These numbers are consistent with bottom-up cost analyses for onshore wind turbines.[22]

When new technologies are introduced into markets, their costs tend to be higher than the costs of the technologies they would displace. Early investments are needed to ‘buy down’ the costs of new technologies along their experience, or learning, curves to levels at which the technologies can be widely competitive (Figure 5-4). In principle, a firm introducing a new technology should consider experience effects when deciding how much to produce and consequently to ‘forward price’, that is, it should initially sell at a loss to gain market share and thereby maximise profit over the entire production period. In the real world, however, the benefits of a firm’s production experience spill over to its competitors, so that the producing firm will forward-price less than the optimal amount from a societal perspective. That phenomenon provides a powerful rationale for public-sector support of technology cost buy-downs.[23]

Figure 5-4 shows the incremental cost for buying down the cost of the advanced technology relative to the conventional technology, as the advanced technology moves along its learning curve. The triangular area between the curves indicates the total cost for buying down the cost of the advanced technology to the level at which the advanced technology is competitive with the conventional technology. The point at which the cost of the advanced technology equals the cost of the conventional technology is not necessarily the asymptotic (long-term) market price for the advanced technology.

Widespread diffusion of new energy technologies depends on a successful chain of research and development, demonstration, deployment, and cost reduction before a technology is commercially viable. Once that stage is reached, its widespread deployment also depends on a range of other factors. A new technology may face a range of barriers to its widespread application. These may include perceived high investment risks, a low energy bill, lack of knowledge about the new technology, high transaction and information costs, uncertainty about resource availability, ‘lock-in’ to traditional

FIGURE 5-4: LEARNING CURVE AND BUY-DOWN COST FOR AN ADVANCED ENERGY TECHNOLOGY



Source: Panel on International Cooperation in Energy Research, Development, Demonstration, and Deployment of the President's Committee of Advisors on Science and Technology (PCAST), *Powerful Partnerships: The Federal Role in International Cooperation and Energy Innovation* (Washington, DC: Office of Science and Technology, Executive Office of the President, 1999).

technologies, lack of interest at the management level, and low technical and institutional capabilities to handle the new technology. Taxes, financing, fiscal policy, legislation, regulation, infrastructure development, education, and capacity building are important to address such barriers.

Information and transaction costs can be the target of specific government initiatives. For example, responsibility for mapping natural resources should lie with the government. Transaction costs can be reduced by simplified permitting procedures, physical planning, use of standardised contracts, and clear regulation for suppliers of electricity, heat, and fuels from renewables. Information costs for new technologies and risk may be effectively reduced through a government testing and certification procedure. Agreements and regulations can promote both awareness and action. Governments, as key sponsors of the educational system in most countries, also have an obligation and opportunity to support infrastructure development and education for practitioners.

Many advanced energy technologies that could play a major role in realising sustainable energy – including biomass, wind, and solar energy technologies – require comprehensive public-sector support throughout the entire energy innovation chain: for research and development (R&D), demonstration, commercialisation, and widespread deployment.

Cooperation between Industrialised and Developing Countries

Efforts to promote sustainable energy in both industrialised and developing countries illuminate the need for closer collaboration between these countries, especially in the areas of technological innovation, strengthening of local capacity, increased training, and information.

There is a great need for technological innovation for energy efficiency, renewables, and cleaner use of fossil fuels in the developing countries. Technical operating environments in these countries are often distinctly different from those of industrialised countries. For example, poorer power quality, higher environmental dust loads, and higher temperatures and humidity require different energy-efficiency solutions than those successful in industrialised-country conditions. Technologies that have matured and been perfected for the scale of production, market, and conditions in industrialised countries may not be the best choice for the smaller scale of production or different operating environments often encountered in a developing country. Realising a sustainable energy future in developing countries will need specific efforts in the areas of technology development, field tests, technology maturation, and market acceleration. Strengthening the cooperation between industrialised and developing countries, but also among developing countries, could be an important driver for this innovation. Cooperation could be through joint ventures, licensing, or local subsidiaries.[24]

In many developing countries, there is a lack of technical infrastructure and a shortage of technical workers. Therefore, an important arena for cooperation between industrialised and developing countries involves the development and strengthening of local technical and institutional capacity. Project-oriented agencies, eager to show results, commonly pay inadequate attention to the development of institutional capacity and technical and managerial skills needed to develop and implement sustainable energy infrastructures. Multilateral or bilateral cooperation is needed to provide training and experience in sustainable energy development for technicians and policy makers from developing countries. This cooperation may also result in technical and financial support for the creation and strengthening of (regional) centres for sustainable energy technology and policy analysis in the developing countries, such that the need for training and information is systematically addressed.[25]

Encouraging Technological Innovation in Developing Countries

Instead of following the example of today's industrialised countries, developing countries have the opportunity to leapfrog directly to modern, cleaner, and more energy-efficient alternatives. Some developing countries are well positioned – from the standpoint of their rapidly growing energy demands, nascent infrastructure, and natural resource endowments – to reap the benefits of technological leapfrogging. In some cases, developing countries may even be able to adopt new technologies with near-zero emissions – resolving the seemingly inherent conflict between environmental protection and economic development.

There are many developing-country examples of technological leapfrogging.[26] One of the most familiar is the widespread adoption of cellular telephones, which has eliminated the need for overhead telephone line infrastructure as a precondition for the diffusion of telephone technology. There are other notable examples of developing countries being the first to adopt new technologies, including energy-related technologies. Developing countries have led the way in several advanced iron-making technologies, including direct reduction using natural gas (Mexico), modern charcoal-based iron making (Brazil), and first-generation smelt reduction technology (South Africa). China is a world leader in biogas technology, and Brazil led the world in the production and use of biomass-derived ethanol as a transport fuel (although shortages in supply have resulted in less consumer interest in recent years).

Leapfrogging over some of the historical steps in the technological development of today's industrialised countries is a widely accepted principle. But conventional wisdom cautions against developing countries taking the lead in commercialising technologies not widely used elsewhere. Because developing countries face so many pressing needs (see Chapter 2), the argument goes, they cannot afford to take the many risks associated with technological innovation. There is reason to modify this view in some situations.

First, developing countries in general – and rapidly industrialising countries (e.g., Brazil, China, India, Indonesia, South Africa) in particular – are becoming favourable theatres for innovation. Most developing countries are experiencing rapid growth in the demand for energy services, a necessary condition for successful technological change. Moreover, many rapidly industrialising countries have large internal markets and are moving towards the development of strong domestic capital markets and market reforms, including energy-market reforms, that will provide more favourable investment climates. In many cases, these countries also have a large cadre of suitably trained engineers and others who can contribute to technological advance.

Second, developing countries need new technologies different from those of industrialised countries. For example, most developing countries are in the early stages of infrastructure development. They have enormous demands for basic materials and need innovative technologies that will facilitate infrastructure development. In industrialised countries, by contrast, the demand for basic materials is reaching the saturation point, and there is little need for fundamentally new technologies for basic materials processing.

Third, early deployment of advanced energy-generation and use technologies that are inherently low polluting offers advantages in coping with the growing environmental problems that are rapidly becoming major concerns in developing countries; end-of-pipe solutions are inherently costly and likely to become more burdensome as regulations tighten. This is an important consideration for most developing countries, where regulations for environmental management are at a very early stage.

Fourth, local manufacturing could lead to larger domestic markets and opportunities for export growth. Lower wage costs, at least in the early stages of economic development, could contribute to cost competitiveness. For example, vernacular architecture, long suited to local climatic conditions and culture, may be intrinsically superior to imported designs and materials yet open to benefits from better processes and materials. Cooking and space heating devices may be similarly open to local reconfiguration.

All these factors suggest that new sustainable energy technologies could reach competitive levels if substantial early deployment opportunities are pursued in developing countries. In addition, substantial benefits may arise from combining local customs and practices with new technologies, processes, and materials. Technological leapfrogging is thus an effective strategy that can help developing countries in the transition to sustainable development.

International Policy Related to Energy Technology Innovation in Developing Countries[27]

The need for energy technological innovation in developing countries stands in sharp contrast to low levels of such activity in developing countries today. Multilateral and bilateral assistance in getting developing countries more engaged in energy technological innovation activities is needed in light of the many pressing development needs. There are also potential benefits to industrialised countries: access to developing-country energy markets and external benefits such as reduced transboundary air pollution and reduced greenhouse gas emissions.

Human and institutional capacity building are needed if sustainable energy technologies are to make contributions in providing energy services for the developing countries. One capacity-building priority is training at providing business development capabilities for companies that will produce, market, and install sustainable energy technologies. Base levels of technological capabilities might be promoted via the establishment of regional institutes ('centres of excellence') that provide training in the fundamentals and management of energy technology. Capacity and institution building is also needed to form and staff public sector agencies and research institutes that can support sustainable energy development. (See Chapter 6 for more on capacity development.)

In addition there is a need for international institutional mechanisms to channel private-sector resources and both bilateral and multilateral public-sector resources from around the world to developing countries for energy technological innovation activities. This could imply strengthening of successful development programs, or creating new international joint ventures or programs for energy innovation activities in developing countries that are supportive of sustainable development objectives. A new initiative could be the creation of a Demonstration Support Facility – as part of the Global Environment Facility (see Box 5-1) – to carry out demonstration projects for new sustainable energy technologies.[28]

Because technologies developed in the industrialised countries are sometimes not well suited to developing-country applications, part of the resources will be

Box 5-1
Technology Transfer and Market Development Promoted by the Global Environment Facility (GEF)

Since its inception in 1991, the Global Environment Facility (GEF) has promoted technology transfer of energy efficiency and renewable energy technologies through a series of projects in developing countries. From 1991 to mid-1999 the GEF approved grants totalling US$706 million for 72 energy efficiency and renewable energy projects in 45 countries. The total costs of these projects exceed US$5 billion.

GEF projects are testing and demonstrating a variety of financing and institutional models for promoting technology diffusion. For example, fourteen projects diffuse photovoltaic (PV) technologies in rural areas through a variety of mechanisms: financial intermediaries (India and Sri Lanka), local photovoltaic dealers/entrepreneurs (Peru, China, Zimbabwe, and Indonesia), and rural energy-service concessions (Argentina). Several other projects assist public and private project developers to install grid-based wind, biomass and geothermal technologies (China, India, Sri Lanka, Indonesia, Mauritania and Mauritius). For energy-efficiency technologies, projects promote technology diffusion through energy-service companies (China), private sector sales of efficient lighting products (Poland), technical assistance and capacity building (China), and regulatory frameworks for municipal heating markets in formerly planned economies (Bulgaria, Romania and Russia). In addition projects provide direct assistance to manufacturers for developing and marketing more energy efficient refrigerators and industrial boilers though foreign technology transfer (China).

The achieved energy savings and renewable-energy capacity installed through GEF-supported projects are small but not insignificant relative to world markets. For example, wind power capacity directly installed or planned for approved projects is 350 MW, relative to an installed base of 1,200 MW in developing countries in 1997. The GEF has approved close to 500 MW of geothermal projects, which compares with over 1,100 MW installed worldwide from 1991 to 1996. There are an estimated 250 to 500 thousand solar home systems now installed in developing countries and approved GEF projects would add up to one million additional systems to this total in the next several years. Replication or ‘indirect’ effects are also key aspects of GEF project designs; through demonstrations, new institutional models, policy changes, stakeholder dialogues, and other project activities. Capacity building is a central feature of most GEF projects and is resulting in indirect impacts on host countries’ abilities to master, absorb and diffuse technologies.

Based on: Mansley, M., and E. Martinot et al., ‘Financing and Partnerships for Technology Transfer’, in Metz et al., *Methodological and Technical Issues in Technology Transfer*, A Special Report of IPCC Working Group III (Cambridge, U.K.: Cambridge University Press, 2000), p. 154.

needed for RD&D to shape new energy technologies to developing-country needs. In addition, research is needed to better understand the consequences of energy technological innovations under local conditions.

Participatory development is now widely recognised as a way of achieving effective technology transfer at all levels of development endeavour. This has grown from a perceived need to move from donor-driven technology transfer to national needs-driven approaches. It can facilitate market transformation through the involvement of firms and consumers. Governments are the most direct and influential actors for promoting a favourable environment for participation at regional and local levels.[29]

Most technology transfer to date has passed along a North-South axis. However, creative means of using bilateral aid, multilateral programmes, and increased access to world capital markets may provide opportunities to increase South-South transfers. Enhancing South-South transfers is important, because developing countries may encounter challenges that are unlikely to be found in industrialised countries, but for which solutions exist in other developing countries. Initiatives to improve the pathways for South-South transfer could include: sharing of information regarding the performance of sustainable energy technologies in developing countries; joint energy R&D and demonstration programmes; and opening markets for sustainable energy technologies from other developing countries.[30]

Instruments of Government Innovation Policy

Finally, we will summarize and discuss a number of governmental policy instruments that can be applied to achieve the required level of energy technology innovation to support sustainability. Nearly all of a country's laws, regulations, and other policies may affect the development and transfer of innovative technologies. Thus government intervention to guide technology development toward realising a sustainable energy system can take a number of forms.

It is useful to examine separately the instruments that can be used to stimulate RD&D in ways that promote sustainability, and those that can guide deployment and dissemination of key innovative technologies. In addition attention is needed for policy instruments dealing with the systemic character of the innovation process.

Interventions to Promote RD&D

Instruments that can be used to steer or stimulate RD&D include:[31]

- *Formulating research priorities*. By formulating research priorities, government articulates desired research areas. This may affect the RD&D agenda of universities, public research institutes, and firms, especially if combined with the formulation of thematic RD&D programs such as improving the energy efficiency of industries, or improving the cost-benefit ratio of wind turbines. The effect aimed at is directing RD&D towards desired, strategically relevant research areas in the energy field.
- *Direct public funding*. By providing direct RD&D funds, often obtained from general government tax revenues, perhaps obtained through a tax on energy consumption, government stimulates firms and research organisations to invest in the development of (specific) energy technologies. Realising a shift

in the spending of RD&D money, government can stimulate the development of promising options that previously had only modest attention, such as specific technologies to improve energy efficiency, to utilise renewable energy sources, or to allow cleaner use of fossil fuels.

- *Technology forcing standards*. Technology forcing standards demand a performance (energy consumption level, emission level) that is not feasible with the existing technology. The requirements induce firms to invest in developing innovative technologies. As an example, this instrument is applied in California to stimulate the development and introduction of zero-emission cars (see Box 2-4, page 72).

- *Corporate technology development agreements*. Government may try to stimulate technological development by negotiating agreements with industries in which they commit themselves to develop a technology, to reduce environmental emissions, or to improve energy efficiency within a certain time frame. A public-private commitment to support RD&D to achieve the formulated goal can be part of the agreement. An example of this approach is the U.S. program 'Partnership for a New Generation of Vehicles', leading to an agreement in 1993 between government and the three major car manufacturers to develop a prototype car that in the year 2005 would be three times as efficient as the 1994 cars.[32]

- *Initiating and stimulating networks*. By initiating networks and cooperation among actors such as firms, universities, and semi-public research institutes on specific issues (e.g., CO_2 removal and storage), government can try to enhance the match between supply and demand of RD&D and the actual exploitation of knowledge and innovative technologies. Such cooperation may result in collaborative RD&D partnerships or the establishment of consortia for the development of a new technology. Through consortia, government can leverage its own financial RD&D resources to induce substantial private-sector investments in RD&D.

Interventions to Promote Deployment and Dissemination of Technologies

Government policy instruments can also play a leading role in the early deployment and widespread dissemination of innovative energy technologies. Some examples of such interventions are:[33]

- *Target setting*. Governments can set ambitious but realistic targets and timetables for enhanced efficiencies in the use of energy, for the use of renewables, and for the reduction of emissions from fossil fuel use. Targets and related government policies and measures provide a strong economic and political message that could unleash the power of the market. An example of target setting is the introduction of renewable portfolio standards (RPS; see Box 5-2), which require that a certain percentage of the

Box 5-2
Texas Portfolio Standards

Under the Renewables Portfolio Standard (RPS) in Texas, retail electricity suppliers have a requirement to include a specified percentage of renewables in their generation portfolio. The policy is backed-up by annual renewable energy generation targets. Texas has set targets increasing to 2,880 MW of renewables to be installed by 2009; this includes the addition of 2000 MW from new renewable generating projects. Wind energy is currently dominating the new installed capacity of renewables with supply costs of around 3 cents/kWh (which includes a 1.7 cent/kWh federal production tax credit).

Projections show that the first year target of 400 MW of new capacity to be installed during 2002 and 2003 will be exceeded significantly. The key factors considered to be contributing to the success of the policy are: clear renewable energy targets, clear renewable resource eligibility requirements, stringent noncompliance penalties, a Tradable Renewable Energy Certificate system that encourages flexibility and minimises costs, and a dedicated regulatory commission that fully involved numerous stakeholders during the detailed design of the policy.

Source: Reprinted from G8 Task Force on Renewable Energy, Final Report, June 2001.

electricity produced is generated by renewable energy systems but lets the market choose the technology (see also Chapter 2).

- *Resource development concessions*. In this approach, governments allocate through bidding or other methods a geographical region to which energy sources are to be developed (e.g., wind energy sources, onshore or offshore) and/or energy services are to be supplied by private entrepreneurs.
- *Dynamic performance standards*. By formulating performance standards as a function of time, government formulates criteria that are likely to affect decisions of firms to invest in the application of innovative technologies. Such standards have been the most common method for reducing specific emissions (e.g., amount of SO_2 per kilowatt hour) or exposure to hazardous substances. Firms are flexible about how they can meet these standards. Dynamic performance standards can also be used to improve the energy efficiency of appliances.
- *Technology standards*. By prescribing or prohibiting specific technologies, government actively seeks the elimination of undesired technologies or the application of desired technologies.
- *Voluntary agreements*. Among enterprises to improve energy efficiencies and/or to reduce atmospheric emissions. In the Netherlands, an agreement

between government and a major part of the industrial sector to improve the efficiency of their energy consumption with on average 18 percent between 1989 and 2000 was quite successful and resulted in an improvement with about 20 percent.[34]

- *Taxes and fees*. By raising taxes or fees, government tries to financially burden 'undesired' behaviour. Taxes and fees are a means of stimulating technology to develop in desired directions by changing the structure of financial incentives: negative externalities are taxed and positive externalities are rewarded. An example can be found in the Netherlands, where small consumers have to pay a high tax on the consumption of energy from conventional sources. Most of the revenues are used to reduce income taxes. This measure turns out to stimulate the use of energy from renewable sources more than energy efficiency. In the Netherlands, in the early 1990s, a small levy on energy consumption was introduced to finance an Environmental Action Plan of Dutch utilities focused mainly on CO_2 emissions reduction and energy efficiency improvement. A similar measure has recently been introduced in Brazil where, following privatisation, new concessionaires are required to spend 1 percent of their after-tax revenues on energy efficiency improvement activities.[35]

- *Tradable emission permits*. Government sets an overall level of allowed, but continually declining, permitted emissions. Companies are issued certificates allocating their share of permitted emissions for a region or country; they are then allowed to either use these or trade them among themselves. (See Box 2-3, page 70, for a discussion of the U.S. SO_2 emissions permit trading program.)

- *Green certificates*. Producers receive a certificate for each predefined unit of energy produced from renewable sources ('green' energy). These certificates can be traded at a national or international market, which will work when combined with other policy instruments like the Renewable Portfolio Standard and/or national agreements on CO_2 emission reduction.

- *Favourable feed-in tariffs*. Fixed uptake prices for renewable electricity delivered to the grid have obtained good results in diffusing technologies (e.g., wind turbines and photovoltaic systems in Germany).

- *Subsidies with 'sunset' clauses*. Subsidies are introduced for a determined time with a clear understanding from the outset that they will be gradually eliminated.

- *Green pricing*. Energy from renewable energy sources is priced higher than energy from conventional, more polluting sources; the price differences are accepted by consumers.

- *Venture capital provision*. A lack of risk capital may be a bottleneck impeding the introduction and subsequent use of an innovative technology. By raising and providing venture capital, government can try to facilitate the final, capital-intensive stages in technological innovation.

- *Technology procurement*. By guaranteeing a certain market demand, government reduces the risks involved in bringing a technology to the market. In Sweden this concept has been applied successfully to early deployment of a number of products including the heat pump (see Box 5-3). As a result, these heat pumps became 30 percent cheaper and 30 percent more efficient.[36]

Box 5-3
Market Transformation through Technology Procurement by NUTEK in Sweden

Governments might use their convening power to create a demand for new technologies and in doing so have a large impact. For example, in the late 1980s, the Swedish government agency responsible for energy, NUTEK, created a technology procurement programme to facilitate a market transformation to products with higher energy efficiency. In the programme, the government acts as a catalyst by convening consumers to define the need, thereby encouraging the equipment producers to meet the need by improving equipment performance and efficiency. The cost to the government is very small, and the programme has a record of more than dozen successful projects.

To illustrate the approach, consider household refrigerator-freezers. About half of the market for such appliances in Sweden is accounted for by a few public and private companies owing apartments. NUTEK convened a group of buyers, who agreed to issue a request for proposals for more energy-efficient, freon-free refrigerator-freezers. The winning model was freon-free, and its electricity requirements were one-third less than for the most energy-efficient model on the market, and two-thirds less than the market average.

The approach has also proven effective for lighting, windows, heat pumps, clothes washers and dryers, and even electric vehicles, where significant market transformations have been observed, and energy use has been reduced by 20 percent to 50 percent, compared to the best products on the market. In addition, the energy-efficient products often have other advantages such as being higher quality and having reduced noise.

The NUTEK technology procurement program has proven to be an efficient mechanism for bringing new technologies into the market. However, other institutional improvements, such as labelling, performance standards, product campaigns, and professional training, are needed in order for the new products to penetrate and saturate the market, thus leading to a sustained impact. These changes need to be made in ways that appreciate the realities of operating business in a competitive environment.

Source: A.K.N. Reddy, R.H. Williams, and T.B. Johansson, *Energy After Rio – Prospects and Challenges* (New York: UNDP, 1997).

Systems Oriented Policy Instruments

When compiling the portfolio of policy instruments to achieve innovations, specific attention should be given to instruments removing *imperfections* in the (national) systems of innovation. In many countries system oriented instruments are heavily under-represented in the portfolio to date. Instead, supporting RD&D in individual companies is often the major objective of innovation policies. More attention should be given to policies and instruments dealing with the building and organization of sustainable energy innovation systems and the management of interfaces between potential partners in the innovation process. Instruments are also needed to create conditions for various forms of learning and experimenting with innovative energy technologies and to provide an infrastructure for strategic information production on the technologies tailored to the needs of actors involved. In addition more attention is needed for policy instruments that can be applied to stimulate demand articulation and to facilitate the search for possible applications of new technologies. Finally, attention is needed for instruments that can be applied to support vision and strategy-development.[37] Some examples of policy instruments are presented:

- *Promotion of clustering and cooperation for innovation*. The cluster perspective to innovation offers useful insights into how innovation dynamics, inter-dependencies, and the related institutions are shaped and defines scope for policy action. Clusters can be characterised as networks of strongly inter-dependent firms (e.g., in the field of wind energy technology), linked to each other in a value-adding production chain, often encompassing strategic alliances with universities, research institutes, knowledge-intensive business services, bridging institutions (e.g., consultants) and customers.[38] The cluster approach in policymaking focuses on facilitating networks and creating the institutional setting that provide incentives for cluster formation or for revitalisation of existing clusters. Policy instruments that can be applied to achieve that may include: providing support and appropriate incentive schemes for collaboration; initiating network brokers and intermediaries to bring actors together (see Box 5-4); facilitating the exchange of knowledge; setting up competitive programs and projects for collaborative RD&D; and ensuring that public institutions cultivate industrial ties.[39]

- *Stimulating research cooperation between universities and industries*. To improve intellectual and technological competitiveness in the global economy, in many countries an effective use of institutional and personal linkages to build cooperative alliances between universities and industries is stimulated by, for example, tax facilities, establishment of technology transfer entities, and exchange of people.[40]

- *Raising public awareness*. Government can provide incentives to raise awareness of the benefits of (new) energy technologies, e.g. by eco-labelling, codes and standards, and community education. Based on increased awareness, governments can interfere to improve the articulation of demands for sustainable energy (e.g., energy efficiency, see Box 5-4), stimulating innovation and technology transfer.

- *Education and training*. As the pace of technology change accelerates, continuous education and training on energy options and technologies to achieve a sustainable energy future will become more critical as a mechanism for technology transfer, in which governments can be an important role. Training and human resource development have been popular development assistance activities. Future approaches can be more effective by focusing less exclusively on developing technical skills and more on creating

Box 5-4
An Intermediary on Energy Efficiency: EMC in India

National-level government agencies acting as intermediaries can also be important in creating incentives and facilitating a market for cleaner technologies. The Energy Management Centre (EMC), an autonomous agency, under the Ministry of Power, Government of India, is an example of a technology intermediary for energy efficiency. EMC has been carrying out a number of initiatives to promote energy conservation and efficiency in India. To begin with, EMC set up and trained 25 agencies (public, private and NGOs) to provide specialised energy auditing and management to consumers in India. Each of these agencies are carrying out an average of 10–12 energy audits annually, and the feed back from the industry is that there is an urgent need for many more such professional agencies to be able to serve the consumers in the country.

EMC also carried out a number of studies in the area of technologies for energy efficiency, issues relating to standards and labelling, as well as implementing a nation-wide energy conservation awareness project. EMC annually organises, through industry associations, about 20–25 training programmes and workshops for wider dissemination of information on energy conservation in the country. To date, it is reported that over 5000 professionals have been provided training in different aspects of energy efficiency. Regular feedback carried out indicated that the participants have actually implemented energy-efficiency projects in their organisations.

EMC was the executing agency for international cooperation projects with Germany, the European Union, and the USA, among others. Under a collaborative programme with the EU, EMC has set up an Information Service on Energy Efficiency (ISEE), jointly with a notional industry association. The database established is expected to contain information on technologies, guide books, manuals, best practice programmes, a list of manufactures, etc., and is expected to fill the gap in information for energy consumers.

The initiatives of the Indian Government implemented through the EMC have resulted in a significant rise in the exposure and awareness on energy conservation technologies.

Source: Metz, B., et al., *Methodological and Technical Issues in Technology Transfer*, A Special Report of IPCC Working Group III, (Cambridge, U.K.: Cambridge University Press, 2000), p. 26.

improved and accessible competence in associated services, organisational know-how, and regulatory management.[41]

- *Legal and regulatory environment*. The establishment of a suitable legal and regulatory framework is an important component of policies and measures for a sustainable energy future. Regulatory policies that rely on performance standards with market-based incentives could greatly enhance sustainable energy innovation.[42]

Conclusions

Technological innovation is crucial to the re-shaping of energy systems in ways that encourage sustainable development. But the development and dissemination of clean, safe, sustainable, and affordable energy technologies is not occurring fast enough or widely enough to realise the goal of sustainable development. Thus, acceleration of the energy innovation process should be achieved through all effective means, including appropriate public policies. Where there has been substantial progress with radically new technologies, it has mainly been based on past government-supported activities for which support has subsequently declined.

Despite the overlap in various phases of the innovation process, it is useful to examine the different stages of the innovation chain: research and development, demonstration, and diffusion. Each stage has distinct requirements and faces specific barriers. Different policy approaches are needed to overcome these barriers.

Firms invest in RD&D to achieve technological advantage. There are, however, RD&D activities that do not offer enough of an incentive for the private sector, but whose results can yield significant benefits to society as a whole. In these cases, where markets fail, there can be good reasons for government to step in and support RD&D efforts. However, technology development is a highly interactive process involving more than the supply or diffusion of knowledge. It implies the need to embed innovation policies in a broader socio-economic context and a shift from top-down to network steering. It also implies that government innovation policies have to deal not only with *market failures*, but also with *system imperfections*.

There are a variety of intervention strategies by which government can enhance technological development. The selection of a strategy depends on how technological development is perceived. In this chapter, four approaches to technology development are discussed, each of them associated with a specific government intervention strategy: the Neo-classical Economic Approach, the Evolutionary Economic Approach, the Industrial Network Approach, and the Systems of Innovation Approach. All four approaches share the view that technology innovation cannot be described solely in technical terms. They reject the linear and sequential model of technological developments and refute the suggestion that technologically optimal solutions will result automatically. Instead technology development is an interactive process, involving economic, technical, and social elements, all of which are highly intertwined, with many actors involved, and whose outcome is innovative technology. Government is one of the actors that can influence technology development and transfer in each stage of the innovation chain.

Major criteria for determining whether government should finance a particular field of energy research can be:

- Is it expected to contribute to achieving a transition to a sustainable energy future?
- Will it strengthen the competitiveness of (national) industries?
- Is the quality of the research infrastructure in the field of interest good enough?

Additional considerations may be:

- Limit the number of topics.
- Optimise the efficiency of public expenditures.
- Strengthen international cooperation.
- Enhance the application of knowledge.

Dealing with imperfections in the system of innovation may also require the following government actions:

- Make sure that there is enough funding for new knowledge creation.
- Improve linkages in the system.
- Help actors to find one another.
- Shape strong user-supplier links.
- Be patient in the process of adjusting the institutional set-up.
- Take note of the need for variety and consistency in the applied policies.
- Stimulate prime movers.

There is concern that spending on energy innovation, from both private and public sources, may prove inadequate to the challenges confronting the world. Spending on energy RD&D has declined since the early 1980. Reported public spending has been falling steadily in industrial countries, from about US$15 billion in 1980 to approximately US$7 billion in the year 2000. Japan and the United States account together for about 80 percent of the year 2000 expenditures. A major share of the money, 47 percent, was spent on nuclear energy. The share of RD&D on energy efficiency was about 18 percent, on renewables 8 percent, and on fossil fuels 6 percent.

There is little information on energy RD&D in developing countries, and with a few exceptions it is likely that spending has been modest.

The innovative process requires investment not only in RD&D but also for starting up the market diffusion of new energy technologies. In recent years, more attention has been given to the phase between demonstrations and commercial competitiveness, i.e., to the phase called early deployment in the innovation chain.

For essentially all technologies and production processes, a substantial amount of experience or learning results from their application, which in turn reduces cost. For various products and processes that are in an early implementation stage, cost reductions have been observed ranging from 10 to 30 percent each time cumulative production doubles. This phenomenon – called learning or experience curve – has motivated private firms to use forward pricing. That is, they initially sell products below production cost under the expectation that learning effects will drive cost down and that profits will be generated later. But for many technologies, including renewables, it may be difficult for an individual firm to recover the costs of forward pricing. Early investments are needed to 'buy down' the costs of new technologies along their experience, or learning, curves to levels at which the technologies can be widely competitive. Here public financial support in combination with other measures can be key to success.

It is concluded that many advanced energy technologies that could play a major role in realising sustainable energy require comprehensive public-sector support throughout the entire energy innovation chain: for research and development (R&D), demonstration, commercialisation, and widespread deployment.

There is a great need for technological innovation for energy efficiency, renewables, and cleaner use of fossil fuels in the developing countries. Technical operating environments in these countries are often distinctly different from those of industrialised countries. Technologies that have matured and been perfected for the scale of production, market, and conditions in industrialised countries may not be the best choice for the smaller scale of production or different operating environments often encountered in a developing country. Developing countries also have the opportunity to leapfrog directly to modern, cleaner and more energy efficiency energy use and supply technologies.

Realising a sustainable energy future in developing countries will need specific efforts in the areas of technology development, field tests, technology maturation, and market acceleration. There is a need for international institutional mechanisms to channel private-sector resources and both bilateral and multilateral public-sector resources from around the world to developing countries for energy technological innovation activities. This could imply strengthening of successful development programs, or creating new international joint ventures or programs for energy innovation activities in developing countries that are supportive of sustainable development objectives. A new initiative could be the creation of a Demonstration Support Facility to carry out demonstration projects for new sustainable energy technologies.

Strengthening the cooperation between industrialised and developing countries could be an important driver for realising a sustainable energy system in developing countries. Participatory development is now widely recognised as a way of achieving effective technology transfer at all levels of development endeavour. Cooperation could be through joint ventures, licensing, or local subsidiaries, among others.

Creative means of using developed country bilateral aid, multilateral programmes and increased access to world capital markets may provide opportunities to increase South-South energy technology transfer as well. Enhancing South-South transfers is important, because developing countries may encounter challenges that are unlikely to be found in developed countries, but for which solutions exist in other developing countries. Initiatives to improve the pathways for South-South transfer could include: sharing of information regarding the performance of sustainable energy technologies in developing countries; joint energy R&D and demonstration programmes; and opening markets for sustainable energy technologies from other developing countries.

Nearly all laws, regulations and other policies in a country or region may affect the development and transfer of innovative technologies. Government interventions can thus take a number of forms. A variety of instruments can be used to guide energy technology that supports sustainable development and to enhance innovation.

Three groups of instruments are discerned: 1) to steer or stimulate RD&D; 2) to foster the deployment and dissemination of sustainable energy technologies; and 3) to remove imperfections in the (national) system of energy technology innovation.

Instruments that can be used to steer or stimulate RD&D include:

- *Formulating research priorities.*
- *Direct public funding of specific RD&D activities.*
- *Technology forcing standards.*
- *Corporate technology development agreements.*
- *Initiating and stimulating networks of innovation.*

Policy instruments that can play a leading role in the early deployment and wide-spread dissemination of innovative energy technologies include:

- *Target setting on e.g., energy efficiency or the use of renewables.*
- *Resource development concessions.*
- *Standards and agreements.*

- *Taxes and fees, e.g., to internalise external costs.*
- *Tradable emission permits.*
- *Green certificates and green pricing.*
- *Favourable feed-in tariffs, e.g., renewable electricity delivered to the grid.*
- *Subsidies with 'sunset' clauses.*
- *Venture capital provision.*
- *Technology procurement.*

When compiling the portfolio of policy instruments to achieve innovations, specific attention should be given to instruments removing imperfections in the (national) systems of innovation. In many countries system oriented instruments are heavily under-represented in the portfolio to date. Some examples of policy instruments are:

- *Promotion of clustering and cooperation for innovation.*
- *Stimulating research cooperation between universities and industries.*
- *Raising public awareness by, e.g., eco-labelling and community education.*
- *Education and training.*
- *A suitable legal and regulatory environment.*

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6 Capacity Development

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The agenda for action on policies to support energy as a means for sustainable development involves key stakeholders within the energy sector itself, within other institutions, in the public sector at large, as well as a number of key players in the private sector. Clearly identifying these critical stakeholder groups – entry points for capacity development – and the role that capacity development can play in reaching sustainable development outcomes in society, the economy, and the natural environment is essential. Capacity development is needed if the critical policy frameworks – including those described in earlier chapters in this volume on functioning markets, the electricity sector, rural energy, and the innovation chain – are to be established. However, in addition to capacity development to support policies, policies are needed to support capacity development. Only with a clear understanding of the role of capacity development in reaching energy goals can this dual linkage to policies and policy frameworks be adequately addressed.

As described in both the World Energy Assessment[1] and Chapter 1 of this volume, energy systems have multiple linkages with the social, economic, and environmental dimensions of sustainable development. To meet human needs and support development, growth, and elimination of the basic conditions of poverty prevailing in much of the world, the availability of energy services is essential. The generation and delivery of these services depend on actions and policies both within the energy sector and in the economy and polity at large (see Figure 1-5, page 29). The marketing, utilisation, and distribution of energy services depend on many factors and institutions that lie outside the 'energy sector' as it is typically understood. Policy definition, legislation, implementation, and monitoring require human and institutional capacities in both the public and private sectors.

This chapter attempts to distinguish between capacity building and capacity development. It addresses why capacity development is a relevant policy topic, identifies the key stakeholders for bringing about sustainable development outcomes related to energy, and reviews key issues for capacity development efforts. Because capacity building opportunities and stakeholders are numerous, it would be easy to conclude that the capacity development challenge is overwhelming. As this is indeed the case, especially in many developing countries, the goal is to specify which capacity challenges should be addressed as priority issues to support a better-functioning energy sector, generating services that support sustainable development at large. Properly addressing these priority capacity challenges will require specific policies as well as public and private financial support. For these reasons, the capacity development challenges related to making energy an engine for economic growth and sustainable development should form an explicit part of the policy dialogue at the national as well as at international levels.

The process of institutional and regulatory reform of the energy industry in developed, transition, and developing countries creates a complex environment for the design, development, and implementation of sustainable energy policy. Around the world, if the goals of sustainable development are to be achieved, *appropriate human and institutional capacities must be developed to design and implement new policies in the energy sector that enable the effective functioning of reformed energy industries, policy entities, and regulatory and coordination agencies*.

Deregulation, re-regulation, and the increasing role of the market have had positive results on the economic dimension of sustainability in many countries. The introduction of competition or (in some cases) new regulation is increasing the allocative, productive, and structural efficiency of the industry overall and, in many cases, is resulting in lower costs and prices for the final consumers. In some places, the segmentation of energy markets into economic and uneconomic components (sometimes corresponding to on-grid and rural off-grid areas, respectively) is raising new concerns over equity in the provision of energy services and the net impact on poor groups even as the macro-economy improves. Access, availability, and affordability are all equally important when considering the challenges of energy services provision. Similarly, increasing public concern over environmental issues linked to energy systems has introduced the need for more complex policy approaches that address local, regional, and global environmental externalities. As institutional roles change, so does responsibility for environmental protection, enforcement of clean production standards, and the internalisation of some environmental costs, requiring the development of new human and institutional capacities.

The dynamic process of reform is generating a new context in which conditions affecting the design, formulation, development, and implementation of energy policies have become even more complex. Liberalisation and the influence of market forces require using indirect instruments to influence the behaviour of energy system players. Decentralised decision making in resource allocation creates new challenges to achieving compatibility between macroeconomic objectives and global and sub-sector energy policy goals. In short, the energy-sector entry points and opportunities for change are more dispersed than ever.

Institutional, systemic, and individual capacity development – along with reinforcement of existing capacities of many different stakeholders – is needed if the energy system is to be instrumental in bringing about sustainability. Each stakeholder plays a different role, and the needs, existing capacities, and new roles of each need to be considered. To determine the scope of the capacity development challenge, the questions *why, who, what*, and *how* must be asked in relation to the roles of stakeholders in contributing to sustainable energy outcomes.

The objective is to focus capacity development efforts on those performance areas where the existing energy institutions are most directly challenged in the new liberalised environment within which energy policy must be formulated, implemented, and assessed. Energy stakeholders need rules to ensure that environment and social policy targets are not negatively affected by market liberalisation and that the benefits of competition are realised and enjoyed by broad groups. State bodies and public institutions will require specialised teams and the development of tools, strategies, instruments, databases, and measures if they are to carry out their duties adequately.

All stakeholders have important, specific roles in policy formulation and implementation. What kind and how much capacity development is needed requires an analysis of their role both in the energy system and in related policy dialogues.

Capacity Development: Meaning, Conceptual Framework, and Dynamic

Capacity development is a broad concept associated with a relatively wide range of actions aimed at ensuring a country's management of development policies and programs.[a] The definition varies in meaning and scope, going from a narrow view of equating capacity building with enhancing individual skills and institutional ability needed to accomplish administrative functions to a broad view of capacity development as synonymous with the term development. There is no general agreement on exactly what capacity development means; however, this fuzziness is useful in forging a consensus on the importance of the topic at large, its meaning, and how it could be operationalised to achieve the objective of using energy as an instrument for sustainable development.

[a] The term 'capacity development' does not, of course, imply that there is no capacity in existence; capacity development includes the building up and strengthening of capacity but it also includes retaining existing capacity, improving the utilization of capacity, and retrieving capacity which has been eroded or destroyed. Thus capacity development does not take place simply through training and additional staff but requires that skilled people be used effectively, retained within organisations that need their skills, and motivated to perform their tasks.

During the 1970s, the trend in terminology was a shift from ‘institution building’ to ‘institutional development’. ‘Building’ implied there was nothing there in the first place, and the failure to acknowledge existing systems, infrastructure, and ways of doing things was seen as insulting and arrogant. ‘Development’, on the other hand, implies improving existing structures.[2] Institutional development has been one of the major areas of emphasis in domestic and international development support.

The World Bank, placing emphasis on human capital and human resources development, emphasises building a critical mass of professional policy analysts and economic managers over the long term who will be able to better manage the development process and ensure that already trained analysts and managers are utilised more effectively.[3] In this approach, human capacity is needed to obtain more efficient and rational outcomes in the overall development process in a given country.

In a broad context, ‘capacity’ refers to the ability of individuals and institutions to make and implement decisions and perform functions in an effective, efficient, and sustainable manner.[4] This definition has three important aspects. First, it indicates that capacity is not a passive state but is part of a continuing process. Second, it ensures that human resources, and the way in which they are utilised, are central to capacity development. Third, it requires that the overall existing context and functions of organisations be a key consideration in designing strategies for capacity development.[5]

Agenda 21 (Chapter 37) places special emphasis on capacity building and provides a comprehensive definition. ‘Capacity building encompasses the country’s human, scientific, technological, organisational, institutional and resource capabilities. A fundamental goal of capacity building is to enhance the ability to evaluate and address the crucial questions related to policy choices and modes of implementation among development options, based on an understanding of environmental potential and limits, and of needs as perceived by the people of the country concerned.’[6] This could be considered an umbrella definition enjoying virtually universal support. The diverse interpretations made of this definition stem from the relative emphasis placed on the various component elements; these variations determine the operational relevance of the concept as well as the action entry points.

The broad concept of *capacity development* revolves around some common elements and approaches. These include:

- Specified objectives: vision, values, policies, strategies, and interests.
- Efforts: will (motivation, drive) energy, work ethic, and efficiency.
- Capabilities: skills, knowledge, and mental sets.
- Resources: human, natural, technological (infrastructure), cultural, and financial.
- Work organisation: planning, designing, sequencing, and mobilising.[7]

Concerns over sustainability, especially with respect to environmental issues, means planning and policy formulation no longer involve merely the 'optimal allocation' of traditional resources or factors of production (energy, land, capital, labour, etc.). The policy challenge today is to address the 'human-environmental system' as a whole, that is, the socio-economic-environmental interactions that are essential components of sustainability. This introduces new capacity challenges.

Natural resources that previously were considered to be common or 'public goods' without limits as inputs to production have come to play a key role as economic goods. Their inclusion in the decision making process of resource allocation requires new capacities and knowledge. This natural resource or environmentally conditioned view is linked to the finite character of some key resources or is due to the irreversible negative impacts their unsustainable use yields as a result of antrophogenic activities.[b]

Different economic sectors, including the energy sector as traditionally understood, are evolving to deal with increasingly complex problems as a consequence of the new natural and economic environment. The need to arrive at a proper equilibrium between economic optimisation, social acceptability, and human ecosystem viability within a sustainable development perspective requires special abilities (capacity) to analyse and formulate responsive policies. It is essential to weigh various alternatives under conditions of high uncertainty and to recommend specific courses of action in keeping with local economic and socio-political realities. This challenge not only requires new capacities but by definition means that the capacities must be integrated across a series of disciplines or sectors in order to meet the goals of sustainable development.

No single capacity development action or programme can meet these ability requirements. Rather, a series of mutually reinforcing actions, phased over a long period, are necessary. The overall aim of capacity development is to launch a set of efforts where the emphasis, weight, and scope of actions and programmes can be adapted to each particular circumstance. The final purpose should be to identify, design, and promote the systematic development of local, national, and regional capacity to introduce and maintain energy systems that are compatible with sustainable development.

Capacity development can therefore be understood as the processes of creating, mobilising, enhancing or upgrading, and converting skills/expertise, institutions, and contexts to achieve specific desired socio-economic outcomes, in this case, in keeping with sustainable development. Capacity development must be achieved through activities at the individual, institutional, and systemic level. ***Capacity building*** *efforts at each of these levels are discrete elements of the* ***capacity development*** *process.*

'At the individual level, capacity building refers to the process of changing attitudes and behaviour-imparting knowledge and developing skills while maximising the benefits of participation, knowledge exchange and ownership. At the institutional

[b] Until recently, no economic theory considered the natural environment as a potential factor limiting growth. No paradigm includes the environment as a specific resource in the economic function. The economic role of the natural resource base and environmental conditions has been analysed and developed relatively recently, in particular in both environmental and ecological economics approaches. The limits of economic models and the scope of economic decision making is an ongoing issue in sustainable development discussions.

level it focuses on the overall organisational performance and functioning capabilities, as well as the ability of an organisation to adapt to change. It aims to develop the institution as a total system, including individuals, groups and the organisation itself. Traditionally, interventions at the systemic level were simply termed 'institutional strengthening'. However, capacity development further emphasises the overall policy framework in which individuals and organisations operate and interact with the natural environment, as well as the formal and informal relationships of institutions'.[8]

These three levels – individual, institutional, and systemic – cut across the temporal dimension: 'Capacity has relevance in both the short (the capacity to address an imminent problem) and long term (the ability to create an environment where a specific change should take place)'.[9] In different countries, different capacities are needed in the short and long term, especially in the context of rapid economic, social, or environmental change. Prioritising these capacity needs is a critical, yet often under-appreciated, part of the development process itself.

One means of doing this is to consider the dynamic dimensions of capacity development. Capacity development is a cycle within which specific intervention points occur. These include:

- Creation: formal or informal long-term training programs.
- Mobilisation: full utilisation of the existing potential.
- Enhancement: measures aimed at dealing with obsolescence by providing short-term courses, workshops, seminars, and other training services.
- Conversion: conscious adjustment of existing capacity to deal with new problems.
- Succession: establishment of certain standards to which subsequent generations aspire.[10]

Finally, capacity development programmes should be based on a set of principles and modalities, including:

- Participatory approaches to define the broader goals of sustainable development.
- Identification of needs, constraints, and challenges.
- Engaging beneficiaries in the design and priority-setting processes.
- Implementing activities that are inclusive, cross-sectoral, and long-term.
- Participatory monitoring and evaluation mechanisms to analyse progress.
- Maximising the benefits of the stakeholders and providing incentives for continued participation. [11]

These essential elements help to define capacity development in this dynamic and integrated perspective. Capacity development is a useful concept to bring together the various elements needed to create an enabling environment for a positive role of energy and the provision of energy services for sustainable development. The *enabling environment* depends on human resources, institutional roles and functions, and systemic integration to respond to challenges in both the short and long term.

The Need for Capacity Development (Why)

In recent years, the concept of capacity development has taken on a new dimension as it has become considered a basic element in governance. This is why it is an essential factor in the discussion of how to achieve sustainable development; without adequate institutional and human capacities in public (and many would argue private) institutions, the conditions of governance needed to bring about sustainable development outcomes cannot be met. Governance implies three key elements: form of political regime; process by which authority is exercised in the management of a country's economic and social resources for development; and the capacity of government institutions to design, formulate, and implement policies.[12] Governance requires capacities in the public system; as governance functions have changed, so too have the capacities required to undertake these functions effectively.

The close relation between capacity development and governance arises from concerns regarding the increasing role of the government to counteract possible distortions of a pure market economy approach to development brought about by structural adjustment programs. In the wake of free market reforms that have spread throughout the world in recent years, governments remain a principal actor in macroeconomic policymaking, infrastructure development, and social programs delivery. Successful markets themselves require frameworks and rules to guide the marketplace. The public management of privatisation, corporatisation, and re-regulation processes also require new efforts to protect the environment. For the institutions of the free market to work, government institutions must also work.[13] In a liberalised economy, different rules – not the absence of rules – are required to bring about the desired economic, social, and environmental outcomes and benefits that public agencies seek.

Governance and capacity development are important linked issues in the context of increasing domestic complexity in the energy sector and in the economy as a whole. Processes of economic and state reform have served to change dramatically the structure of the energy system overall (including institutional, legal, and regulatory aspects) as well as the roles of different stakeholders within the energy system. In many countries a more developed and complex energy system is emerging. It is characterised by new functions for public and private institutions, as well as new institutions and new players. With an increasing number of players, or stakeholders, such systems operate on a different rationality than the 'pre-reform' system and respond to different market and non-market incentives (see Chapter 2). Thus new governance challenges related to the overall processes of market and macroeconomic reform that are much broader than the energy sector itself must be addressed.

The key governance and capacity development challenges associated with the new energy system include a more dis-integrated and segmented industry; more volatile behaviour of key macroeconomic variables such as prices; and changes in the legal status of relevant production and distribution companies, including new legal and property rights. As part of this process of change, conflicts between short-term and long-term interests in both the public and the private realm need to be resolved. These issues are linked to changes in the overall macroeconomic context within which the energy system operates; they are further overlaid with challenges posed by new technological developments that change dramatically the principles and processes of the energy industry (Chapter 3 and 5).

The role and responsibility of government and public institutions to provide energy products and energy services, or to generate the conditions by which private entities generate energy services to meet domestic, industrial, and public sector needs, become increasingly complex in a reformed, re-regulated, or more market-oriented economy and energy system. In vertically integrated public utilities, the challenge of meeting the energy service needs of large unserved populations was enormous, but the option of cross-subsidisation within the electricity sector, across fuel types, or between provinces and populations, in order to achieve social goals was possible. This was indeed a feature of many publicly managed energy sectors and frequently remains a feature within domestic energy systems even as they change today.

Secure, predictable, and sufficient energy supplies and services are a pre-requisite for value-adding activities, industrial production, and economic growth; they are fundamental to the growth and development process itself in all countries. (See Chapter 1 and World Energy Assessment)

A major development and governance challenge in today's rapidly changing energy system, within which vertical integration and cross subsidisation is discouraged, is how to meet the energy service needs of unserved, or poorly served, populations, especially poor and rural populations. In some cases, market mechanisms can be used much more effectively, especially where there is evidence of economically viable, decentralised energy options and the ability to pay. How to promote and support access to commercial energy and modern energy services to broad shares of the population totally outside the market and without possibilities of access under pure market rules is, however, an unresolved central challenge for many governments and is a critical governance issue. It is one of the principal reasons why capacity development in relation to the new energy system is needed.

Environmental challenges and increasing international attention to natural resource issues (acidification, global warming, biodiversity threats, land degradation, deforestation, and desertification) involve the energy system as both a source and a victim of many of these changes. Climate change mitigation, vulnerability, and adaptation issues imply, in many senses, a totally new approach to the energy problem, requiring new skills, new conceptual frameworks, new methodologies, new ideas, and new solutions.

Overall, the energy system and the energy industry are increasingly internationalised. In many cases, processes of regional integration and globalisation impact local entrepreneurs and may increase or decrease their decision-making space. New opportunities are emerging, along with new risks and challenges, that impact on the private sphere just as the changing role of the state has impacted on the public sphere.

This dynamic and often highly uncertain situation is characterised by the dispersion and heterogeneity of information (quantitative and qualitative). The process of obtaining and managing information and basic data sets related to energy confronts new challenges and requires new instruments and tools. Inadequate data, lack of reliable statistics, inadequate access to information, the cost of information, and discontinuity of data collection are major problems in undertaking energy or environmental analysis. These problems impact the effective functioning of both the private and the public sector; however, public and private stakeholders vary enormously in their ability or incentive to pay for the improved information management systems needed to support energy systems that address the challenges of sustainable development.

No single stakeholder, sector, or public institution commands the mandate or capacity to resolve the complex governance, energy, and capacity development challenges and their linkages to issues of social equity, environmental sustainability, economic efficiency, and public sector management. Moreover, the challenges are not static but change in dimension, location, priority, and cost as the energy system evolves.

The need to address and approach any energy-sustainability problem with an interdisciplinary perspective and multi-stakeholder approach was one of the major conclusions of the ninth session of the Commission on Sustainable Development (CSD-9). No single stakeholder can afford to address the multiple dimensions of the energy challenge and no single discipline (economics, engineering, or political science) includes in its analytic perspective all the various elements related to resolving the energy challenge.

The new risks and challenges require innovative answers to old and new problems in an open and free debate; they also require a search for more flexible and pragmatic strategies, approaches, tools, instruments, and actions to overcome conventional public sector approaches developed over the last two decades. A better understanding and a clearer diagnosis of the structure and functioning of new energy systems is needed but is often absent in the discussion of macroeconomic reform, governance, and the role of the state. The new operating environment in which energy solutions must be found suggests a new and essential role for government in terms of its responsibilities to make markets and the energy system work. These changes also impact the behaviour of the private productive sector, the scientific and technical arenas, and civil society. These are among the most important reasons why capacity development is needed.

Stakeholders as Subjects and Objects of Capacity Development (Who)

In the framework of energy for sustainable development, a priority objective is to identify the various stakeholders and their explicit roles in the energy 'arena'. To be a relevant stakeholder (group) in this discussion, the link to producing better, more sustainable energy outcomes must be clear. Stakeholders can be from the public or the private realm. They are the 'natural' addressees of capacity development and capacity building efforts as a means to bring about different outcomes at the national and local levels. Stakeholders can also be an important means of transmitting or replicating critical capacities; as such, they are both subjects and objects in the capacity development discussion. Some of the most important stakeholders in the energy for sustainable development discussion include:

- Government (the public sector, civil service, and representative officials).
- Private productive sector (including the energy industry and other producers of non-energy goods and services).
- Civil society (including non-governmental organisations and representative groups).
- Academia/research/specialists/scientists/consultant institutions.
- Media.

Acceptance of the idea that there are conceptually distinct 'target' or stakeholder groups does not imply segmentation of the capacity development process. Capacity building activities should be part of a process occurring within a systematic framework in which the message is integrated and consistent across groups in order to yield the desired outcome. Capacity building activities with all stakeholder groups should occur with a common objective: to design, develop, implement, promote, and support energy policies and outcomes that enhance sustainable development in all its dimensions.

Table 6-1 proposes fourteen principle stakeholder groups based on their distinctive functions within the energy sector and the energy system more broadly understood – the 'who' of capacity development. The list of functions outlined is not exhaustive but highlights some of the key roles and responsibilities that impact the overall ability of energy systems to respond to the challenges of sustainable development.

The stakeholders and activities included in lines 1 through 6 are the broad category of 'government' and are related to policies concerning administration and regulation. These functions involve political, legal, institutional, economic, social, environmental, and technical dimensions, and are thus highly complex in nature. This first group has responsibility for the political dimension. The government area establishes the basic regulatory principles depending on the orientation of a country's socio-economic and energy policies and regulatory norms. Within government, energy issues

TABLE 6-1: STAKEHOLDERS IN ENERGY FOR SUSTAINABLE DEVELOPMENT

STAKEHOLDER	FUNCTION / ACTIVITIES
1. Legislative authorities/ elected officials	Set national political priorities; social, economic, and environmental goals; legal framework conditions.
2. Government macro-economic and development planners	Define development goals and macro policy; general economic policies; cross-cutting issues; subsidies and trade policy; sustainable development goals, and frameworks.
3. Government energy authority or ministry	Set sectoral goals; technology priorities; policymaking and standard-setting functions; legal and regulatory framework; incentive systems; federal, state, and local level jurisdiction.
4. Energy regulatory bodies	Have monitoring and oversight functions; implement the regulatory framework; administer fees and incentives.
5. Market coordination agencies	Dispatch entities; have operational coordination functions; interface with industry investors; information brokers.
6. Non-energy governmental authorities/ministries	Sector policies; cross-cutting issues; inter-relation with energy policies; public sector energy consumers; require energy inputs for social services provision.
7. Energy supply industry	Private companies and public utilities; manage energy supply, electricity generation; fuels management and transport; finance some R&D.
8. Entrepreneurs and productive industries	Business development; economic value added; employment generation; private sector energy consumers.
9. Energy equipment and end-use equipment manufactures	Supply equipment for the energy industry and other industries, including vehicles and appliances; impact energy end-use efficiency; adapt/disseminate technology; finance some R&D.
10. Credit institutions	Financing options for large- and small-scale energy generation; capital provision for energy using enterprises; financing options for household energy consumers.
11. Civil society/non-governmental organisations	Consumer participation and awareness; oversight and monitoring; environmental and social advocacy; equity considerations.
12. Energy specialists and consultants firms	Strategic advice, problem definition and analysis; systems development; specialist services delivery; options analysis; information sharing.
13. Academia and research organisations	R&D, knowledge generation, and sharing; formal and informal education; technical training; technology adaptation, application, and innovation.
14. Media	Awareness raising, advocacy; information sharing; journalistic inquiry, watchdog functions; monitoring, public transparency.

have both public and private goods considerations. Capacity development needs in this broad group are the greatest in a rapidly changing context due to the overall responsibility of the public sector to support the effective functioning of energy service delivery systems as a means to support economic growth, human well being, and environmental sustainability.

Stakeholders listed in lines 7 through 10 combine to form the main elements of the private productive sector. This sector includes both the production of energy supplies and services and the use of energy as an input to support activities and outcomes in other parts of the economy and society. Among this category of stakeholders, energy is a marketed commodity fulfilling a mostly private goods function. Availability of services, security of energy supply, and stability of energy prices are common key considerations for these stakeholders. Credit institutions, while in some countries capitalised by the public sector, operate under market or increasingly market-oriented conditions and are included here as part of the private sector. Capacity development needs among this broad grouping are largely focused on the role of energy and energy options in supporting productive activities consistent with sustainable development.

In many cases, the stakeholders listed in lines 11 through 14 are part of the 'supply' or availability of capacity for the rest of the system. They are often seen as a means of transmission for capacity development. They include non-governmental or civil society organisations (NGOs/CSOs) working in support of sustainable development, as well as energy specialists providing academic or technical expertise. Of equal importance is the role of this combined group as advocates for change, sustainable development, and improved social, economic, or environmental outcomes. As a balance to the political dimension reflected by government, and the productive dimension reflected by the private sector, this collective stakeholder grouping often is the primary agent advocating the interests of 'society'. In terms of capacity development needs, the collective grouping requires correct, timely, and transparent information on energy and the role of energy in supporting sustainable development.

These three groupings may be more useful organisationally when thinking about capacity development than the concept of the energy 'sector'. The energy sector is composed of public sector entities (e.g., the ministries of energy, power, or electricity), private sector companies, energy research organisations, and expert groups. The fourteen stakeholder groups each have specific functions and therefore different capacity building needs.

1. Legislative Authorities and Elected Officials. Although there is no agreement on the exact role of the state, key functions for the public sector include the establishment and maintenance of a judicial system that promotes human rights, law and order, and enforcement of property rights and contracts; stewardship for overall economic growth objectives; protection of the environment; formulation of social policies that promote equity and livelihoods for the population; the regulation of monopolies and internal and external trade; investment in social and economic infrastructure, including health, education, research, and development; and equitable access to information, sometimes referred to as 'transparency'. In short, although private enterprise may play a significant role in social progress and economic growth, governments are ultimately responsible for creating the framework for development. Therefore, the public sector, especially elected officials, must have the capacity to identify problems and to formulate and implement appropriate policies. They must have a basic understanding of the role energy plays in national development, of energy bottlenecks, and of alternatives to support domestic growth and poverty reduction. Broader public participation in debate and decision making is often called for so that key priorities reflect a consensus within society. The effective performance of these functions requires accountability. Capable governments are therefore associated with sound governance.[14]

2. Government Macroeconomic and Development Planners. The short- and long-term sustainable development aspirations of a country must be concretely reflected in national development strategies and macroeconomic frameworks. Related policies must promote economic stability and sustainable growth, and the role of the environment and natural resources base, both as an input to growth and as impacted by growth, must be considered. Energy cuts across these issues, and energy choices – especially those related to fuels, technology paths, and service delivery systems – must be considered by planners at the macro-level for several reasons. These include the critical impact of energy on overall economic performance, the interrelationship between energy and the natural resources base, and the local, national, and global environmental impacts linked to energy. Energy services are essential to meet the household, productive, and other needs of the population, and must be a critical element in overall planning. Too often considered as an input to an overall production function, energy services generation and utilisation must be approached in a much more sophisticated fashion by planners in today's rapidly changing macroeconomic context.

3. Energy Ministries. Energy sector policymaking is the responsibility of dedicated energy agencies or ministries in most countries. Incorporating social, environmental, and economic objectives in these policies (rather than merely the energy supply or distribution objectives themselves) is a key challenge. The multiple linkages between the energy system and the objectives of sustainable development must first and foremost be available in the human and institutional capacities within these dedicated energy agencies. Public sector functions previously undertaken by these agencies related to electricity generation and distribution are shifting to private entities or are being restructured to fall under the responsibility of different groups. However, these agencies retain the important function of granting (to private and public enterprises) the responsibility for exploiting different segments of the energy production chain. It is critically important that these ministries consider different energy sources and technologies, drawing on both conventional and renewable energy, to meet the energy service needs of the society and economy.

Not only are central or state-level energy agencies critical. In fact, in many countries the effective functioning of energy policy is actually determined at the local level. It should be noted that the actions of different levels of government agencies (national or federal, state, regional or departmental, and municipal) are usually asymmetrical. They do not have the same functions, attributes (or capacities), or responsibilities in terms of energy. The importance of each agency, and its needs for capacity reinforcement, will depend on the specific legal system of each country. In many cases, the ability of local agencies to be effective in supporting energy policies for sustainable development will hinge on the allocation of state resources to the local level, which is in turn impacted by fiscal policy and the allocation of public resources among different administrative levels. Local government officials and institutional capacity are especially important in meeting the rural energy challenge. National level goals and plans aimed at improving rural energy services cannot succeed unless there is adequate capacity (human, institutional, and financial) at the local level where programmes and services must actually be delivered.

4. Energy Regulatory Bodies. The oversight functions of the often newly created regulatory agencies relate to the supervision and monitoring of compliance with regulatory norms and with provisions contained in contracts of stakeholders involved in energy generation, distribution, and sales. In addition to determining which functions correspond to each level, the basic regulatory framework must define the institutional characteristics and roles of the respective energy entities. Resolving conflicts among various stakeholders is also part of the regulatory function, as is interpreting norms, organising public hearings when conflicts arise, and issuing decisions. These functions are dependent on the legal frameworks that govern the energy sector. In many cases, these regulatory bodies are new and the role of regulation has changed as a result of changes in the energy sector and overall macroeconomic reform. The newness of the regulatory agencies and the new and changing roles of regulators are the principal reasons why this is a priority stakeholder group for capacity development.

5. Market Coordination Agencies. As part of power sector reform, market co-ordination agencies are assuming new roles, responsibilities, mandates, and liabilities, particularly in the case of electric power (and eventually natural gas). In large part, this involves management of the wholesale power market – a function that not only affects the energy sector (understood as generation and distribution) but also has a direct impact on other energy supply chains and the effective functioning of productive sectors by assuring stability or predictability of a major input to productive processes. It is essential that these functions be clearly established and specified in the corresponding regulatory norms determined by other stakeholders including legislators, policymakers, and regulators.

6. Non-Energy Ministries and Agencies. Non-energy governmental actors need a clear understanding of the relevance of energy in their own area of policymaking and implementation. Inadequate coordination among policy sectors usually results from a lack of understanding about how sectors interact with and influence each other, particularly in countries where public sector entities such as ministries of health or education are major consumers of energy. Secure and affordable energy supplies are essential, as they impact the function and cost of activities in other sectors. Not just other national agencies, but also local and municipal authorities, have an impact on energy outcomes. Many countries, at various levels of economic development, have inadequate coordination of policies, activities, or fiscal incentives among sectors and agencies. This undermines a country's ability to pursue energy pathways that are consistent with sustainable development objectives even when this is the stated goal in national-level plans.

7. Energy Supply Industries. As reforms to increase private sector participation expand, the industries generating and distributing electricity, fuels, and energy services function under different institutional and property right schemes (sales of assets, concessions, associations, mixed ownership, etc.) and all have different capacity needs. As discussed in Chapter 4, energy strategies for rural areas pose a special challenge to energy supply industries. Strategies for rural areas must address the issues of poverty reduction and equity in service provision – issues that fall outside a purely 'economic efficiency' driven industry perspective. Rural energy solutions require specialised approaches and knowledge to solve specific social and livelihood problems to improve human welfare. Particularly in the poorest countries, rural energy programmes can make a significant contribution to reducing human labour; making traditional sources of energy (like biomass) more efficient; improving energy applications such as cooking or water pumping; promoting access to modern energy sources (such as electricity); increasing productivity in rural activities; and improving access to information. Rural energy consumers are potential markets that must be adequately understood in terms of needs, size, and economic capacity. These issues require adequate policies and public sector commitment to gain the attention of the energy supply industries and energy entrepreneurs.

8. Entrepreneurs and Productive Industries. Energy plays a key role in both the production and consumption of goods and services. Many productive sectors – including environmental protection, industry, transport, agriculture, mining, commerce, and finance – depend on and influence energy policy; they also require energy services. These sectors affect the natural resources base and environmental conditions linked to energy and therefore impact sustainability. Energy efficiency – a key issue in sustainability – must be addressed not only within the energy sector (which would focus only on supply-side issues) but also in the many industries that use energy and therefore in the policies that govern these industries. Thus non-energy stakeholders must be addressed in any capacity development process, particularly by enhancing knowledge of the linkages between energy and the policies and activities of other productive sectors.

9. Equipment Manufacturers. Domestic equipment manufacturers play two roles with regard to energy issues: 1) they produce the industrial equipment that supports the generation of electricity and heat energy to produce energy services (turbines, boilers, transmissions units, etc.), and 2) they manufacture the capital goods and equipment used throughout the economy in the consumption of energy and electricity (motors, pumps, smelters, electric light fixtures, etc.). In this sense, equipment manufacturers are important on both the demand and the supply side of energy. In efforts to promote energy efficiency and lower emissions from carbon fuels, many countries are adopting programmes of energy efficiency through standards and labelling, providing market share incentives for end-use equipment manufacturers. In other cases, the rising costs of electricity and fuels as a result of market liberalisation and the removal of subsidies is reducing demand for the energy equipment produced by these industries. New energy technologies developed abroad often require the support of domestic industry for ancillary equipment production and installation, especially in the case of renewable energy technologies. In all cases, additional management, planning, sales, and market research capacities are required to support changing energy systems in line with sustainable development objectives. Where energy plans and policies have not addressed equipment manufacturers, it has proven difficult to reach these goals.

10. Credit Institutions. The financing sector has a key role to play in expansion of the energy system, especially in financing environmentally sound technologies or energy efficiency programmes. Credit institutions and financial organisations are often cited as important barriers to energy efficiency actions. The 'culture' dominating the financial institutions does not seem to understand the potential benefits of energy efficiency projects or renewable energy systems; project assessment methods tend to measure financial feasibility in short time horizons or mandated payback periods. Moreover, financing institutions may not have experience in providing consumer credit to support household and small-business energy options. They may lack experience with low-volume lending, and the associated high transaction costs are unattractive to commercial banking institutions even when the financed activities are shown to be economically viable. Programs to raise awareness of the need for small loans and to provide information on alternative project evaluation techniques, blended credit programmes, and a wider range of financing options can help credit institutions and the financing sector play a key role in sustainable development.

11. Civil Society and Non-governmental Organisations. Non-governmental organisations (NGOs) make a major contribution to creating awareness and consciousness raising on the rights of citizens within the civil society, especially as energy consumers. When consumers have adequate information about options, they can have a powerful impact on changing energy use patterns through the choices they make about end-use equipment and fuels. This contributes to an improved equilibrium among the various dimensions of sustainability (economic, social, and environmental), which in turn contributes to increasing the welfare of consumers as a result of increased efficiency in the energy industry. In many countries, energy sector reforms have had mixed impacts on consumers, with different income groups and regions experiencing different impacts. Any effort to build capacity within civil society or among interest groups should provide access to transparent information about what actually is occurring in terms of services availability and prices, knowledge of citizens rights (and obligations), opportunities to participate in public debate (public audience), and organising capacity. NGOs are often more than advocates in programmes to deliver energy and other services in rural areas, actively participating as energy entrepreneurs, trainers, or credit providers based on their commitment to social and environmental development objectives. In many instances, NGOs are called upon to fill the capacity vacuum resulting from public sector downsizing. In the absence of continuity of civil servants and public sector employees, NGOs can serve as both 'capacity receptors' and as 'capacity builders', fostering local organisation, education, and skills formation. Civil society organisations can play a key role in the process of building networks among specialist institutions in order to support stable patterns of collaboration and accelerate the interaction between different energy stakeholders involved in sustainability issues.

12. Energy Specialists and Consultant Firms. Issues related to regulatory frameworks or conditions imposed to enable the functioning of market mechanisms (bringing related consequences in the economic, environmental, and social dimensions) are particularly relevant for this group of stakeholders. As specialists on a wide range of energy issues, these stakeholders can promote access to transparent information on critical linkages and energy options. As the ethical dimension of alternative energy pathways is playing an increasing role in determining the sustainability of the energy system, the credibility of market mechanisms to promote energy service availability can be assessed by properly informed experts. Energy consumers, providers of equipment, and producers of end-use energy consuming equipment all need information and knowledge about opportunities for increased energy efficiency in the energy industry as well as in other industries if economic improvements are to be obtained. Energy specialists can be instrumental in assessing trends and making information available that promotes energy outcomes that support, rather than undermine, the goals of sustainable development. Too often, available expertise within a country is inadequately linked to policymaking, analysis, and review.

13. Academia/Research Organisations. The ways in which the domestic research and development capacity of a country could be affected (positively or negatively) by more sustainable energy policy frameworks is an important consideration. Similarly, scientists, applied researchers, and technology developers can contribute to sustainable development, supporting energy solutions by finding an adequate equilibrium between decentralised interests and objectives (economic in nature) and the global or aggregated concerns (environmental or social) of society at large. Issues associated with the incorporation of new technologies, conditions for transfer of technology, and especially the identification of technology needs to overcome local development obstacles, are among the key challenges for these stakeholders. These stakeholders can also be essential in developing new options to increase the energy supply to rural areas through the development and adaptation of new technologies. Considering that technology should be needs-oriented, a clear understanding of the energy needs of major groups and identification of the role of various energy sources and technologies in satisfying these needs is a first step in developing the capacity of academia and research organisations. A critical capacity challenge is how to maintain, enhance, and fund domestic scientific and applied research capacities to support new energy pathways.

14. Media. Media and public information channels (radio, television, newspapers and other print media, etc.) can contribute to creating awareness in civil society regarding the role of energy in local and national sustainable development. Media can be instrumental in sharing information about energy efficiency and consumer choice, renewable energy options and success stories, and viable new energy technologies to support local development. Media can draw the public's attention to the important social, economic, and environmental issues linked to current energy systems and can enhance democracy in decision-making processes related to energy policies through contributing to public opinion formation. This can serve to influence policy-setting processes by generating broader interest among voters in energy system reforms and improvements. Media is therefore a key stakeholder as an opinion builder on many energy and development issues. They carry responsibility for providing adequate information on the key issues based on a clear knowledge of the sector. Specific media training is needed in some cases to share correct information on the relationship between key energy issues and sustainability.

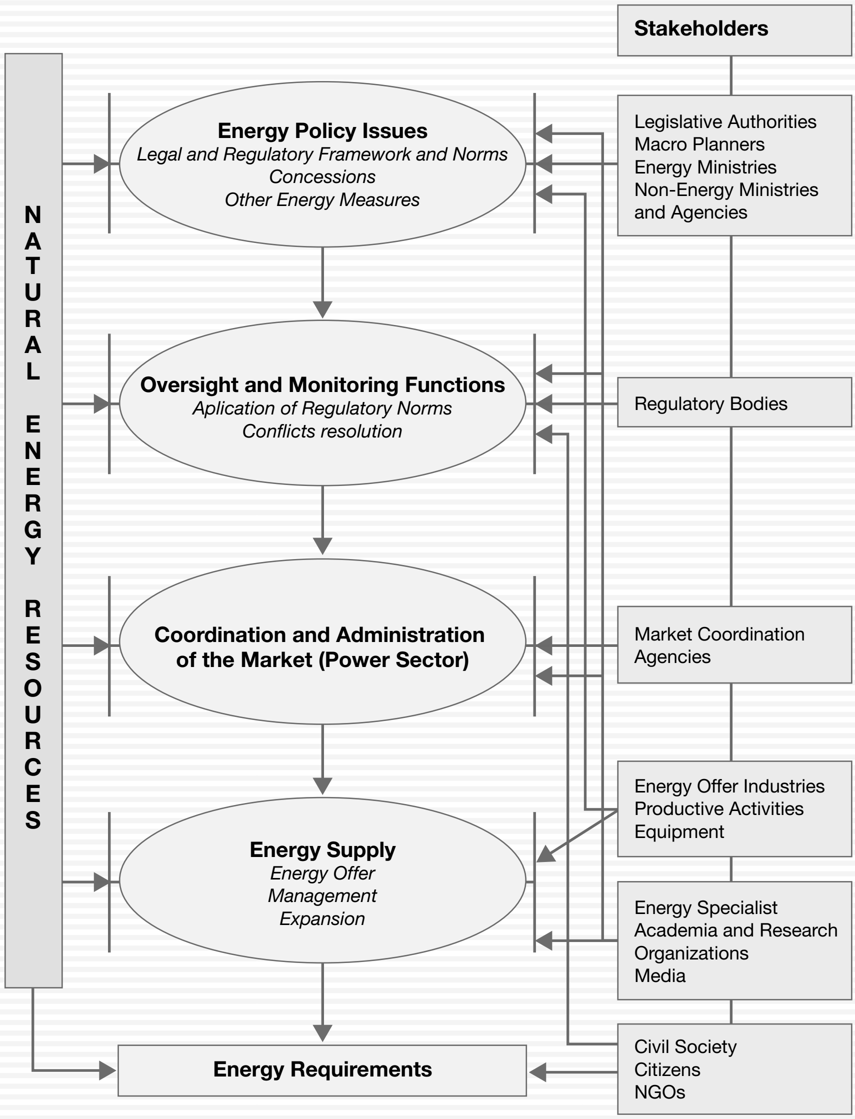
The objective of capacity development and the priority topics to be addressed in capacity building activities for each stakeholder group depends on the particular stakeholder's role or function in the energy system. Figure 6-1 illustrates the various functions and their relationship to each other.

With so many stakeholders, what should be emphasised in capacity development efforts? In every case, that depends upon which stakeholder groups are essential to underpin the functioning of the entire energy system, both within the energy sector as it is commonly understood, as well as in terms of the overall relation between energy issues and other development challenges. Some stakeholder groups clearly cannot fulfil the challenge of supporting sustainable development outcomes unless certain issues regarding relative roles and sequencing are taken into account. UNDP has developed a clear argument in favour of prioritising capacity development aimed at public institutions:

'Notwithstanding the reassessment of the role of governments in the economy and society that took place during the 1980s, there is now a broad consensus among development thinkers and practitioners that a 'capable government', able to perform key functions effectively, is a precondition for development. Thus, most capacity-development analyses and strategies, and much donor support for capacity development, remain focused on the public sector. This is so, even though it is recognised that the role of non-governmental organisations will be more significant than in the past in all spheres of economic, social and political life in most countries, and that the inter-actions between non-governmental organisations and governments have contributed significantly to the emergence and legitimacy of capable governments'. [15]

In the case of energy, the most critical public constituencies for capacity development are macro-planners, energy policymakers, and new regulatory agencies in restructured energy sectors. As the process of energy sector reform, utility restructuring, corporatisation, and re-regulation proceeds, a priority area for capacity development

FIGURE 6-1: THE ROLE OF THE ENERGY SYSTEM STAKEHOLDERS



is in new regulatory agencies and for new regulators. In many countries, regulatory capacities are weak or do not exist and the objectives of market reform, in terms of economic optimisation and social improvement, cannot be reached unless effective regulatory capacities exist to direct the functioning of the market.

For sustainable development objectives to be achieved, new capacities are needed within a quickly changing energy public sector as well as within the private sector. The private sector includes not only credit institutions, businesses, and industries that invest in energy production and consume energy services, but also civil society, consumer groups, the scientific and research community, and media organisations. The development of these new capacities is not entirely a public sector responsibility. Public-private partnerships on capacity development will be required, especially with regards to the introduction of clean, efficient new energy technologies, including in developing-country markets.

Topics for Capacity Development: Stakeholder Needs and Interests (What)

Capacity development must address, develop, and reinforce the functions of various stakeholders in relation to their role in the energy system. It must also consider the linkages among stakeholders in determining responsibilities for different outcomes in the system as a whole. Capacity needs assessment will be specific to each country but should focus on which new or additional capacities are needed to respond to new market or technological conditions that constrain or define the energy system in that country.

In suggesting some of the priority topics for capacity building efforts at the national (and regional) level, it is useful to return to the three broad categories of stakeholders listed earlier: government (stakeholders 1–6), the private productive sector (stakeholders 7–10), and others including academia, specialists, NGOs and media (stakeholders 11–14). These grouping are based on the common functions that loosely correspond to the political, productive, and social-relations roles they respectively play.

The first group, *government or public institutions*, are the priority target group in most capacity development programs because the process of reform implemented in many countries has two key effects on the state structure. First, it creates the need for new skills in relation to the new economic environment, new functions, new scope of decision making, and new problems. Second, the reform process often decreases the capacity of the government, especially human capacity, by reducing governmental infrastructure and precipitating the transfer of the most qualified civil servants to the private sector.

In the energy sector, as in other sectors, government and public sector institutions are needed to ensure the effective administration of policy. Energy policy implementation requires individual, institutional, and systemic strengthening oriented to: assessment (diagnosis), problems identification, objectives definition and prioritisation, targets identification, strategies development in a framework of shared power, instruments proposal, actions and means of implementation, activities development, and tools management to develop and present analysis. Financing capacity development efforts in the public sector will require allocating needed resources within national and sectoral budgeting processes. In developing countries, it may also require reprioritising development assistance support away from technology demonstration projects towards capacity building support for policy setting, implementation, and monitoring.

The topics requiring attention by the public sector because of their impact on the policy environment include:

- Energy and sustainable development linkages.
- International and national development context.
- Characteristics of the national energy system.
- Energy linkages to other sectors.
- Energy linkages to social and environmental goals.
- Energy supply diversity and security.
- Rational use of energy resources.
- Energy technology options and trend.
- Nature and scope of the rural energy challenge.
- Organisation and regulation of energy industry.
- Alternative models of regulation and legislation.
- Roles of subsidies and taxation.
- Market and non-market incentive and penalty systems.
- Conflict assessment and management.
- Feasibility of alternative energy strategies.
- Capacity to assess future energy scenarios.
- Regional and sub-regional integration.

While governments must build the initial frameworks for sustainable energy policy, the *private productive sector* includes key players in bringing about the economic, social, and political viability of these plans. In the case of industry and the private sector, public policy can be used as a means to mandate that small but crucial resources be allocated to support capacity building efforts within business and industry focusing on sustainable development objectives. Capacity development for the private sector (including credit institutions, entrepreneurs, equipment manufacturers) has to be enhanced in topics including[c]:

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[c] These topics are in addition to basic general knowledge on energy and sustainable development linkages that all the stakeholders should have.

- Impact of energy sector reform and re-regulation on productive activities.
- Size and nature of existing and potential energy markets.
- Business opportunities in energy in urban and rural areas.
- Alternative business models for financing energy services.
- Information on existing technologies and new options.
- Concessions, licensing, royalties, and other options.
- Market analysis to identify options for environmentally sound technologies.
- Demand-side options for energy efficiency.
- Alternative means of project evaluation and financing.
- Impact of global and regional trade on domestic markets.
- Opportunities related to global environmental conventions including the Kyoto Protocol.

The ‘others’ grouping of stakeholders is so heterogeneous, a single listing of capacity development topics is difficult. Country specificity must be the determining factor here. Since this group can serve as a means for capacity development, its members must have accurate information about the actual energy conditions in the country that can be shared with other stakeholders as a basis for effective policy debate, formulation, and implementation. Capacity development for this group should focus on how this information can be captured, shared, and improved upon. This includes topics such as:

- Availability, quality, and actual costs of current energy services.
- Domestic trends in production, social services, and environmental quality.
- Role and market power of consumers in supporting change.
- Impact of energy scarcity on women, ethnic groups, and rural populations.
- Impact of macroeconomic reform on energy prices and services.
- Technological options available internationally to improve energy systems.
- Consumers’ willingness and ability to pay for improvements in services.
- Alternative models of services delivery and financing.
- Energy and sustainable development linkages.
- The world energy context, energy supply security, and the impacts of globalisation.

Because of the close relation between some stakeholders on particular issues, there will be areas of overlap that should be taken into consideration in the design of capacity building efforts and programmes. The involvement and dialogue among national actors and stakeholders including representatives of governmental and non-governmental institutions is essential to address change in energy systems consistent with the goals of sustainable development. Involving multiple stakeholders in the process of defining capacity development strategies is essential if the strategies are to succeed, as is national political commitment to carrying them out.

Institutional Issues and Implementation (How)

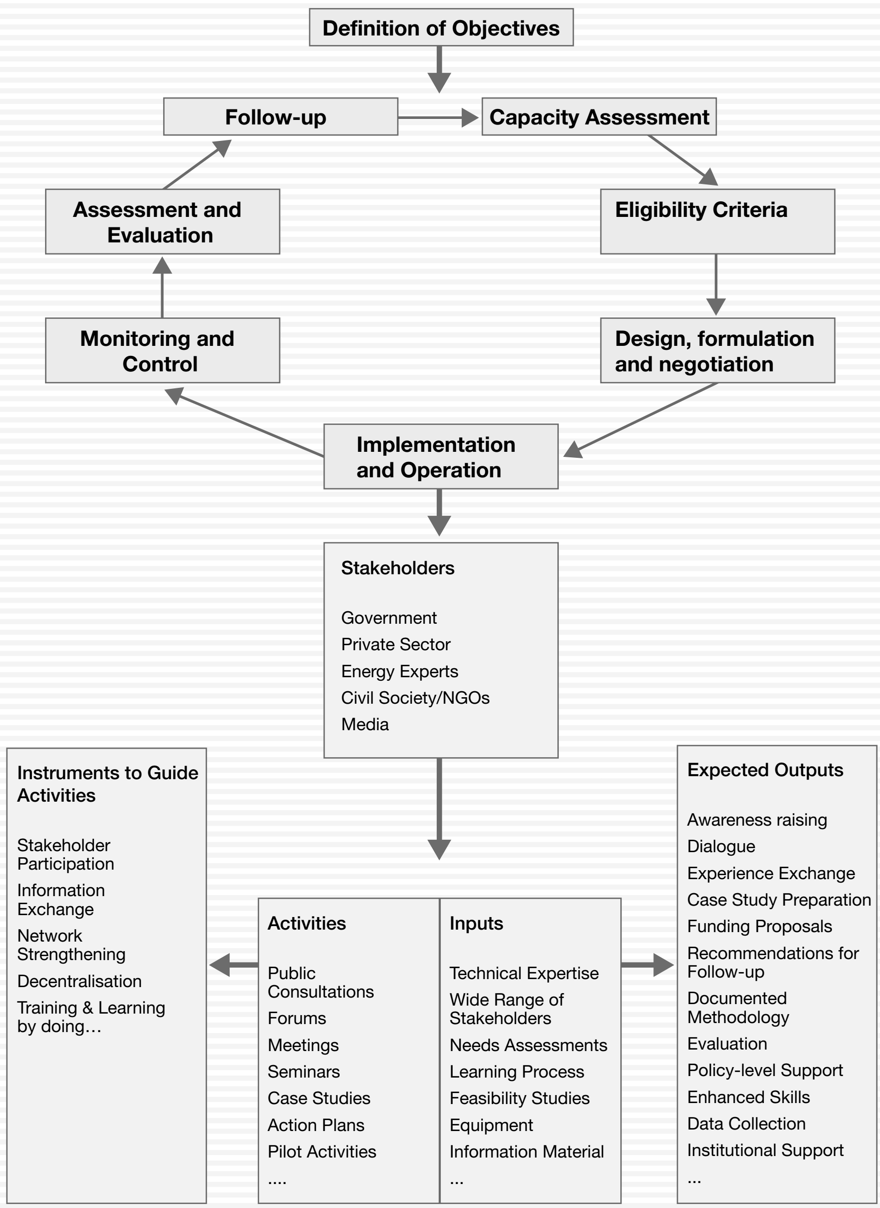
Capacity development interventions seek to introduce government policy teams and other stakeholders to new approaches and methods, to expose them to research and innovation, and to change perceptions in order to improve their decision making and ability to address challenges. Any attempt to apply new concepts and methodologies to tackle development problems in which these groups have both experience and interest will encounter some natural resistance. Capacity development is part of a long-term process and requires commitment in the public sector over time. Short-term capacity building activities may enable some changes in policy definition or analysis but only long-term attention to capacity development will bring about energy system change overall.

A capacity development programme has to be seen as a continuous process that, by definition, must take into account the context and environment within which change is to be brought about. It must therefore identify the barriers and constraints to that change.

Capacity development programmes are complex from a technical and administrative point of view and require an integrated management framework. The various institutions involved (government institutions, donor agencies, academic institutions, NGOs) should design and implement actions within an integrated capacity development plan. Such integration implies coordination, articulation, continuity, recognition of a dynamic and dialectic process, flexibility to introduce necessary changes, and the development of capacity building efforts as part of a cyclical process. Figure 6-2 illustrates the capacity development process, which is iterative and has both a short-term and a long-term dimension.

The starting point for any capacity development process is a clear *definition of objectives*. The more specific the defined objective is, the more concrete, targeted, and outcome oriented the results will be. While it may sound simplistic, this is in fact the most challenging aspect of the capacity development process. When the outcomes to be achieved are clearly defined, it is also more likely that the appropriate stakeholders relevant to attaining those outcomes will be identified. The potential outcomes of energy capacity development include: introduction of market instruments to expand the quality, accessibility, and affordability of energy services; establishment of a new energy regulatory system; mechanisms to expand rural energy services; or

FIGURE 6-2: CAPACITY DEVELOPMENT INTERVENTIONS: PLANNING AND IMPLEMENTATION CYCLE



mechanisms to introduce clean energy technologies suited to local resources conditions. These are among the most challenging issues to be addressed in terms of enhancing the role of energy systems to support sustainable development outcomes. By starting with the outcome to be achieved, rather than the institution to be strengthened or the target group to be trained, the design process identifies that a multi-stakeholder capacity building process will be required. To define a clear objective, the actual state of affairs on that topic must be well understood or at least previously analysed. For example, failure to look at the actual household energy consumption patterns in a rural area might lead capacity development efforts to focus only on rural electrification if the importance of thermal uses of energy for heating, cooking, and agricultural processing is not identified and understood.

Capacity assessment is the next stage in the cycle; it helps to determine which capacities already exist within the stakeholder groups identified as part of the overall effort. In most cases, the country (or at least the region) will have indigenous existing capacity (perhaps within academia, consulting firms, or NGOs). Capacity assessment will also provide basic information on key human, information, or institutional gaps. At this stage, it is also useful to identify the capacity mobilisation, enhancement, conversion, creation, or succession needs among the stakeholders. Many capacity development processes have focused too narrowly on the 'creation' element only. Such training-based exercises may fail to take into account existing competencies, may miss the opportunity to share knowledge, and may fail to lead to change. Identifying existing sources of knowledge, information, and experience on the given topic is essential. Capacity assessment is double-edged: it involves assessing the capacities of those who are to be the subjects of the development process in addition to assessing the capacities of those who are to be the objects, or means of transmission, of capacities.

Eligibility criteria essentially refers to establishing means to narrow the range of individuals or participants in capacity building efforts with a view to achieving the maximum impact for a given effort. This will involve hard choices as the need and desire for opportunities to expand knowledge and abilities will in almost all cases outstrip the availability of opportunities for individuals and institutions. The criteria for eligibility, participation, and support will differ depending upon the outcome to be achieved, but may include age, language, education, institutional affiliation, and experience with a given topic. Poorly targeted capacity building efforts will not lead to successful outcomes. If made transparent, eligibility criteria can contribute to stakeholder buy-in and institutional commitment. They can also serve as an important means of verification and evaluation in looking at the overall results of the capacity building effort over time.

Design, formulation, and negotiation needs to involve specialists in training, human resources development, and organisational management. The budgeting processes to determine the costs of the effort, how it is shared among stakeholders, or how elements are recovered should be critical factors in this stage. National, and in some cases regional and international, sources of expertise and experience will need to be identified in conceptualising the overall effort. Institutions selected as capacity developers must have demonstrated competencies, the ability to respond to the client need or training demand, and a real commitment to the topic at hand. A realistic timeframe will need to be determined. Global evidence has shown that the more concrete, hands on, operational, and outcome oriented such efforts are, the more likely the possibility of success. For example, training courses on regulatory options or models are one way of building capacity to establish effective regulatory and oversight functions for restructured utilities. Equally important are exchanges with actual regulators from other countries who have dealt with similar issues. Such exchanges enable institutional and individual experiences with reform processes, dispute resolution, and regulatory change to be compared, assessed, and refined to fit the domestic reality.

Implementation and operation will involve different sources of expertise as well as stakeholders from different constituencies. In this stage, the role of domestic expert institutions, NGOs, and regional experts is central. Good organisation and consistency in the delivery of capacity building activities is essential. Implementation plans must rely on accurate knowledge of existing expertise and capacity availability at the regional and global level. It may be necessary to organise a systemic means to share information about the available expertise as well as about whatever financial resources are available to facilitate the participation of potential actors. Too often, such information is fragmented at the national level, resulting in underutilization of capacities that do exist. Electronic information storage, exchange, and research is creating new implementation options. Adequate mechanisms for consultation and participation and good-quality knowledge management and information dissemination will all be key elements. An accurate understanding of individual constraints and motivation to take part in the process, as well as the 'stakes' or beneficial outcomes desired by the participants, will be a key in determining individual and institutional motivation and commitment to success. Institutional coordination is a key challenge in this stage, but in all stages is critical to the success of the process itself. Capacity development should be demand driven, inclusive, and participatory to be sustainable and effective.

Monitoring and control is essential to track progress while the process unfolds and gives an objective basis to determine if adjustments are required. If domestic needs and circumstances change, even the best-designed programmes of capacity development must be modified. Monitoring for cross-sectoral integration of issues, or cross-institution team building, should be considered. Here, too, the effective use of modern information management systems will be extremely important. Monitoring and control mechanisms should be linked to the management of budgets and training resources in order to allow for mid-course corrections if the external or policy environment changes.

Assessment and evaluation should involve organisations and individuals who are not primarily responsible for the capacity development effort itself. This is not to say that every programme must be independently verified to be successful, but it does imply that difficult or unsuccessful elements of the experience can be more accurately analysed by more disinterested parties. Assessment and evaluation should look at the design and implementation phases and seek to assess if outcomes or institutional processes changed as a result of the capacity development effort. Assessment and evaluation have both a short-term mediation function as well as a longer- term systems design and redirection function. The assessment phase should also consider stakeholder satisfaction with the short-term training, consultation, or awareness raising processes as well as commitment to the longer-term capacity change that is the overall goal. Follow up and improvements in capacity development processes is the logical outcome of effective monitoring and evaluation.

To design good capacity development programs, it is useful to examine the kinds of problems that frequently confront such programs. Potential problems may occur in the following areas.

- *Capacity needs assessment*. Sometimes needs and priorities are not identified or training packages are accepted and implemented that have no direct relationship to domestic needs or critical energy challenges.

- *Financial resource constraints*. Local and global resources to promote, support, and maintain the capacity development activities may be scarce.

- *Institutional coordination*. Because sustainable development challenges are interrelated and cannot be addressed by a single agency, strong co-ordination is needed among various agencies and ministries.

- *Lack of cooperation and collaboration*. Competition for external funds and/or competing mandates and responsibilities may prevent collaboration.

- *Non-optimal resource allocation*. Failure to review existing capacities in research institutions, NGOs, or regional centres of excellence may result in underutilisation of installed capacity at the national or regional level.

- *Financial management*. There may be little or no administrative capacity to implement budgets allocated to support capacity development. External funds may be poorly managed if they are perceived as free goods.

- *Cost-effective assessment*. Capacity building efforts may fail to target the best recipients to obtain the desired policy impact or outcome.

In summary, capacity development programmes should take advantage of and reinforce the emerging lead role of the State in managing sustainable development including the relevant role of energy in sustainability, in the energy sector itself, and in all sectors.

The key role of the State is particularly relevant in relation to institutional issues. Capacity development should focus on designing and supporting the most appropriate institutional frameworks compatible with existing structures and policymaking practices but also prepare new institutional capacities that are needed with respect to a rapidly changing energy sector. Capacity development on the role of energy for sustainable development must not be limited to the 'energy sector'.

Institutional articulation remains one of the critical factors affecting the consolidation of effective sustainable development policies. Even if the institutions exist and rules, regulations, and competencies are allocated, a considerable gap may exist between the existing infrastructure and its function in reality. Greater attention is needed on the importance of forging effective inter-institutional mechanisms and governance structures to ensure coherence in policy efforts and sustainability of outcomes generated.

The most significant issue for successful capacity building outcomes is to ensure a clear mandate and sphere of authority within government structures and to ensure that relevant staff constitute a competent team with the skills needed to carry out sustainable energy programmes, policies, and development pathways. A competent technical team is the result of a process involving knowledge, experience, and expertise development and is closely related to the governance of the system.

Capacity development is an iterative process requiring a long-term commitment, implemented through many short-term actions, including the dedication of resources and personnel by the public sector. It should serve to compensate for the vacuum resulting from public sector downsizing through adjustment policies. To be effective, capacity development efforts must incorporate well-defined, specific outcomes or goals from the start.

Sustainability, Monitoring, and Evaluation

Capacity development is a dynamic and continuous process and, as such, sustainability must be guaranteed by adequate financial resources, an adequate institutional framework, continued existence of the institutions where the capacity is installed, and permanence of the human capacity developed. The monitoring and evaluation of capacity development is a complex task. Many factors beyond the control of governments and aid agencies and not easily anticipated in designing capacity development strategies influence the outcome of capacity development efforts.

Monitoring and evaluation are also complex because much of the post hoc assessment of capacity will inevitably involve qualitative rather than quantitative judgement. For example, the quality of policymaking includes the quality of the process through which policies are made, the degree to which consensus building is sought, and hence the acceptability of the policies themselves. Evaluation of uniquely quantitative information such as the number of policymakers trained will yield little to no effective information as to whether policies and their outcomes are changing socio-economic conditions.

Benchmarks for monitoring and evaluation will be developed at the design stage, reflecting the priorities selected for interventions, based on the analysis of critical constraints. It is important, however, that the monitoring process is as broad as possible in examining progress or lack of progress since achievements may be hindered by constraints that were not adequately addressed at the design stage. The monitoring process provides an opportunity to reorient interventions accordingly.

'In developing national programs, much more emphasis is needed on the assessment phase, and on the analysis of why capacity problems have emerged. It is also essential that far greater attention be given to the issues of how skilled people are used, to the broad framework of incentives, and to the managerial capacity which is necessary for effective utilisation, motivation and retention of skilled people'.[16]

Monitoring and evaluation are themselves important functions for which capacity may need to be developed, and provisions for it should be included at the design stage.

Final Considerations and Conclusions

1. Capacity development can be understood as the processes of creating, mobilising, utilising, enhancing or upgrading, and converting skills/expertise, institutions, and contexts to achieve specific desired socio-economic outcomes, in this case, in keeping with using energy as an instrument for sustainable development. Capacity development must be achieved through activities at the individual, institutional, and systemic level. Capacity building efforts at each of these levels are components of the capacity development process. Strategies for capacity development require a realistic time horizon since the development of capacity is a long-term process. The strategy will need to be multi-layered, addressing major stakeholder groups including those outside the 'energy sector' in order to address the capacity constraints and problems that impact energy outcomes.

2. The enabling policy environment needed to support the effective functioning of markets; power sector reform; technology innovation; and the establishment of frameworks to reach social, environment, and economic objectives related to energy cannot be created or maintained unless specific attention, funding, and public policy are directed towards establishing the institutional and human capacities needed to create such an enabling environment. Capacity building needs, and the longer-term process of capacity development, must form an explicit part of any successful strategy to use energy as an instrument of sustainable development.

3. The public sector, both at national and local levels, is the key target and recipient of capacity development. Capacity development needs and activities must be addressed not only at the national or federal level, but must include local regulatory agencies, public sector institutions, and local stakeholders. Capacity development in central level agencies may serve to address the

overall macro-framework issues needed in the energy, credit, technology, and related sectors, but will not translate into effective action with sustainable outcomes at the local level unless specific attention is devoted to local capacity needs. The emergence of a 'capable state' not only is central in discussions regarding governance and sustainable development, but should be a central objective with regards to the energy system as well. Capacity development in energy must be interdisciplinary, including economic, social, and environmental considerations linked to energy to support policy definition.

4. As the process of energy sector reform, utility restructuring, corporatisation, and re-regulation proceeds, a priority must be to develop capacity in new regulatory agencies and for new regulators. These capacities in many countries are weak or do not exist and the objectives of market reform, in terms of economic optimisation and social improvement, cannot be reached unless effective regulatory capacities exist to direct the functioning of the market.

5. For sustainable development objectives to be achieved, new capacities are needed within a quickly changing energy public sector as well as within the private sector. The private sector includes not only businesses and industries that invest in energy production and consume energy services, but also credit institutions and equipment manufacturers. The development of these new capacities is not entirely a public sector responsibility. Public-private partnerships on capacity development will be required especially with regards to the introduction of clean, efficient new energy technologies, including developing-country markets. Capacity development to enhance public-private sector collaboration and linkages should be developed and supported. These stakeholder groups are often very disconnected in developing nations.

6. Rural energy challenges require much greater attention to capacity building if social goals and equity objectives are to be met. While technical, institutional, and entrepreneurial capacity does exit in rural areas, it must be harnessed, enhanced, and effectively directed to address the rural energy challenge. In many cases alternative approaches to capacity building will be required and specialised skill sets must be emphasised in identifying the protagonists of capacity development efforts. This is especially the case regarding rural energy challenges and the role of women and women's groups. Specific attention must be given to 'engendered' perspectives on problem and solution identification as well as approaches to enhance service provision. Organised women's groups can be an important means of capacity development in rural communities, including in the development of entrepreneurial skills and rural energy service provision mechanisms.

7. Traditional approaches to capacity building in the scientific and research community that focus only on education and training, narrowly defined, are unlikely to result in the skill set needed to effectively innovate, adapt, and apply energy technologies to address real development and growth issues.

Capacity development with this stakeholder group must squarely address the needs to produce innovations that can be applied to produce results; to generate economic opportunities; and to address socially relevant development needs. In the extremely resource-constrained R&D environments that characterise many developing countries, public policies to redirect a small part of commercial energy revenues toward R&D activities that look at energy-related sustainable development goals can have a high social, economic, and environmental impact and should be encouraged.

8. Capacity development is a continuous process. Priorities must be domestically defined and resources prioritised within national resource allocation processes. Means of verification and follow up should form part of the design of capacity development processes to ensure that capacity building efforts lead to the desired changes in social, economic, and environmental outcomes. The role of civil society organisations can be critical in supporting this feedback loop. The various stakeholders both within the energy sector and linked to energy utilisation should be seen both as the subjects (ends) of capacity building as well as the objects (means) of further capacity development. A key challenge is focusing scarce resources for capacity building on key agents of change who can contribute to longer-term national capacity development at the central and local level.

9. In developing countries, the small (and declining) number of independent research groups and institutes that focus on energy issues is a fundamental obstacle to developing the necessary capacity for effective changes in energy systems. Existing regional networks of energy institutions should be supported and new cross-regional networks should be established to share information on common problems. These are an excellent means to build South-South and South-North cooperation and have proven to be an effective means to support sustainable energy solutions. In general, these groups remain under-supported by the international community.

10. International funding and support should focus more on the institutions and stakeholders that bring about energy systems change and not merely on specific projects. Project-based funding emphasises technology selection and does not support institutional capacity and local sustainability. The international community, especially multilateral development assistance agencies mandated to support sustainable development, poverty reduction, and economic growth objectives, must place greater emphasis and support on capacity development as the focus of development assistance and as an overall means of achieving these objectives. While domestically driven capacity-needs identification must be the overriding principle, the international community can be a critical support of these goals. There is a role for the international private sector in supporting domestic capacity development as well; however, this is only likely to be effective in cases where clearly defined national goals and institutional roles exist.

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Abbreviations

CAFE	Corporate Average Fuel Economy
CC	Combined Cycles
CCGT	Combined Cycles Gas Turbine
CDI	Capacity Development Initiative
CFL	Compact Fluorescent Lamps
CSD	Commission on Sustainable Development
CSOs	Civil Society Organisations
DME	Dimethyl Ether
DSM	Demand-side Management
DU	Distributed Utility
EIA	Energy Information Administration
EMC	Energy Management Centre
EqIA	Equity Impact Assessment
FACTS	Flexible Alternating Current Transmission System
GEF	Global Environment Facility
GDP	Gross Domestic Product
HDI	Human Development Index
IEA	International Energy Agency
IGCC	Integrated Gasifier Combined Cycle
IPCC	Intergovernmental Panel on Climate Change
IPO	Initial Public Offering
IPPs	Independent Power Producers
IRP	Integrated Resource Planning
ISEE	Information Service on Energy Efficiency
ISO	Independent System Operator
LCP	Least-cost Planning
LPG	Liquefied Petroleum Gas

MDGs	Millennium Development Goals
NG	Natural Gas
NGOs	Nongovernmental Organisations
OECD	Organisation for Economic Co-operation and Development
PPA	Power Purchase Agreement
PV	Photovoltaic
PV SHSs	Photovoltaic Solar Home Systems
R&D	Research & Development
RD&D	Research, Development & Demonstration
RETS	Renewable Energy Technologies
REWSUs	Rural Energy and Water Supply Utilities
RPS	Renewable Portfolio Standard
RTD	Research and Technology Development
SLPG	Synthetic Liquefied Petroleum Gas
TSO	Transmission and System Operator
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNDESA	United Nations Department of Economic and Social Affairs
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organisation
VES	Vehicle Emission Standard
WCED	World Commission on Environment and Development
WEA	World Energy Assessment
WEC	World Energy Council
WHO	World Health Organisation
WSSD	World Summit on Sustainable Development
ZEV	Zero Emission Vehicle

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