part V

Are Sustainable Futures Possible?

Part V brings together the analysis of challenges presented in Parts I, II and III and the analysis of resources and technology options in Part IV by considering whether sustainable futures are possible. Can combinations of resource and technology utilisation be envisioned that meet all of the sustainability challenges? The analysis presented is at three levels: the overall global system using a range of alternative energy scenarios, plus analysis of two critically important areas: rural energy in developing countries and transportation. A final section looks at the relationship between energy and more widespread economic prosperity.

The analysis indicates that it is possible simultaneously to address the range of sustainable development objectives.

- **Continuing along the current path of energy system development is not compatible with sustainable development objectives.**
- **Realising sustainable futures will require much greater reliance on some combination of higher energy efficiencies, renewable resources, and advanced energy technologies.**
- **A prerequisite for achieving an energy future compatible with sustainable development objectives is finding ways to accelerate progress for new technologies along the energy innovation chain, from research and development to demonstration, deployment, and diffusion.**
- **Providing access to affordable energy services to people in rural areas poses particular challenges. But it also offers considerable opportunity for improving the lives of billions of people within a relatively short period. Promising approaches include decentralised solutions, appropriate technologies, innovative credit arrangements, and local involvement in decision-making, and especially new mechanisms at the local level that have lower transaction costs.**

- **Transportation is a key area with its rapid growth and high dependence on fossil fuels. By combining new fuels, both fossil and renewable, with near-zero greenhouse gas emissions and a better mix of improved modes of transportation and vehicle performance, it appears possible to meet sustainability criteria.**

Any conceivable energy system that would address all sustainable development objectives simultaneously will not be realised without changes in the current policy environment. Creating such an energy system will require policy action at national, regional, and global levels.

Addressing the Sustainability Challenge: Alternative Scenarios

The construction and analysis of scenarios provides a method for exploring future energy systems and their implications. Scenario construction is not a method for predicting the future; however, by combining plausible and/or interesting assumptions the analysis provides insights as to possible positive and negative characteristics of alternative futures. In constructing energy scenarios, the first questions are: Can combinations of resources and technologies be envisioned that meet *all* sustainability challenges *simultaneously?* Or are there unavoidable trade-offs, e.g., must a choice be made between economic growth and environmental protection? Having identified some "desirable" futures, characterised by meeting all sustainability criteria, the next question is: What would it take to bring about such energy futures in terms of incentives, institutions, rules, and regulations?

Scenario construction involves applying various combinations of assumptions about what world events and trends will affect the energy sector. The issues to be addressed include population growth and age distribution, economic activity and its composition, consumption and production patterns, and limitations in terms of environmental degradation, availability of land and other resources, as well as technologies for energy supply and demand that exist or may be envisioned. The resulting scenarios can then be evaluated in terms of sustainability characteristics.

The World Energy Assessment undertook such a study of how the future could unfold in terms of economic growth, population trends, and energy use (Nakićenović, Grübler, and McDonald, 1998).[14] It started from the premise that, by 2100, 6 to 8 billion additional people – more than doubling today's world population – will need access to affordable, reliable, flexible, secure, and convenient energy services. It assumed that gross world product would grow by a factor of 10 to 15 during the century. It then constructed three sets of energy scenarios (some with multiple variants) by combining assumptions about resources and technologies in a variety of ways. The scenarios were evaluated in terms of compatibility with indicators of sustainability. The WEA concluded that there are indeed a large number of combinations of energy efficiency improvements, renewable energy utilisation, and extensive use of advanced technologies that would have the potential to meet sustainable development criteria.

The WEA scenarios were based on mid-1990s technology, and incorporated only limited improvements in energy efficiency. Utilising advanced fossil fuel technologies discussed in Part IV of this volume would increase the potential for sustainability even more than the WEA scenarios express (see Box 4 for an example). Since the WEA scenarios were presented, there has been no comprehensive energy modelling linking scenarios to the full set of sustainability challenges.

BOX 4. TOWARDS A 2000 WATT PER CAPITA SOCIETY

The Board of the Swiss Federal Institutes of Technology has developed the vision of a "2000 Watt per capita society by the middle of the 21st century". A 2000 Watt per capita energy demand corresponds to 65 GJ per capita per year, which is one third of today's per capita primary energy use in Europe, and slightly below the global average. Assuming a doubling of GDP (gross domestic production) per capita within the next fifty years, the 2000 Watt society implies a four-to-five fold reduction in primary energy use, allowing for some influence of structural change on less energy-intensive industries and consumption patterns.

This vision challenges R&D to improve energy and material efficiency. The findings suggest that new technologies and supporting organisational and entrepreneurial innovations are needed to meet this goal. Some of those technologies and commercial services are available today, but are scarcely applied due to obstacles and unfavourable conditions.

These early findings need further in-depth analysis, but they indicate that the vision of a 2000 Watt per capita society is likely to be technically (and eventually economically) feasible and that its implementation strongly depends on policy priorities in the future.

Sources: Jochem, E., et al., Steps Towards a 2000 Watt Society: Developing a White Paper on Research & Development of Energy-Efficient Technologies, Final Report *(Zürich: Centre for Energy Policy and Economics, 2002); Goldemberg, J., et al., "Basic Needs and Much More with One Kilowatt per Capita",* Ambio *14, no. 4-5 (1985), pp. 190-200.*

14. These scenarios are summarised in the World Energy Assessment. The texts are available in United Nations languages at http://www.undp.org/seed/eap/activities/wea/, and thus not repeated here.

Continuing along the current path of energy system development is not compatible with sustainable development objectives.

A large number of scenarios have been constructed, however, aiming at understating the climate change situation.[15]

All of the WEA scenarios supply the desired level of energy services within the constraints of energy resource availability, and lead to a substantial decrease in emissions of air pollutants; however, only some are consistent with the UNFCCC objective of stabilising atmospheric concentrations of carbon dioxide and other greenhouse gases. Two scenarios lead to concentrations of less than 450 parts per million (ppm) by 2100, stabilising some half a century later. This is a considerable achievement, as it represents only a gradual increase from current concentrations of about 370 ppm. It has not been established at what level stabilisation would be needed to achieve the objective of the UNFCCC to "prevent dangerous anthropogenic interference with the climate system".

The considerable differences in expected total energy use among the scenarios reflect different approaches to addressing the needs for energy services in the future, and they demonstrate clearly that policy matters. Achieving the sustainable development scenarios will require a substantial increase in private and public research, development, and deployment efforts to support new energy technologies. Otherwise, most clean fossil and renewable technologies, as well as many energy-efficient end-use technologies, may not reach competitiveness. (The mix of needed efforts may vary depending on the maturity of the specific technology.) Significant technological advances will be required, as will incremental improvements in conventional energy technologies.

In terms of their expected high growth in energy demand, developing countries are well positioned to take advantage of innovations in energy technologies and policies that support them. In general, sustainable scenarios require significant policy and behavioural changes within the next several decades to be achieved. The window of opportunity for making such changes is at most a decade or two. The decisions made during this time will largely determine whether the energy system continues to evolve along current lines or whether it achieves the transition towards more sustainable development paths.

Once basic infrastructures and energy-intensive industrial capacity are in place, investment largely shifts from new capacity to replacement. New technologies can be introduced in this phase, but they take much longer to affect average system performance, as they occur at the much slower rate of replacement investments. If advanced systems and technologies are not selected in decisions about new investment during the next few decades, nations, corporations, and the world will be locked into older, less sustainable options, and sustainability might not be achievable for a long time, if at all. Thus the achievement of sustainable development demands a global perspective, a very long time horizon, and the timely introduction of policy measures to reduce barriers and create incentives for advanced technologies and systems.

Because of the long lifetimes of power plants, refineries, steel plants, buildings, and other energy-related investments such as transportation infrastructures, there is not a sufficient turnover of such facilities to reveal large differences among the alternative scenarios before 2020, especially in the industrialised countries. But the seeds of the post-2020 world will have been sown by then. Thus choices about the world's future energy systems are relatively wide open now. This window of opportunity is particularly significant where infrastructure has yet to be installed, offering the possibility of a rapid introduction of new, environmentally sound technologies.

Clearly, the insight that there are desirable energy futures that meet a whole set of sustainability criteria is very positive. However, these energy futures are unlikely to happen in the current context of market conditions, incentives, and institutional and regulatory structures at the national, regional, and global levels. Options that can be implemented to change the current context are discussed in Part VI.

The Rural Development Challenge

Between 1970 and 1990, rural electrification programmes reached about 800 million additional people. Some 500 million saw their lives improve substantially through the use of better methods for cooking and other rural energy tasks. Despite these enormous efforts to improve energy services to rural populations in the past thirty to forty years, the unserved population has not

15. These are reviewed by the Intergovernmental Panel on Climate Change. 2000. Special Report on Emission Scenarios (available at www.ipcc.ch).

decreased significantly in absolute numbers – it remains about two billion people.

Although the unavailability of adequate energy services in rural areas is probably the most serious energy problem confronting humanity in the near future, rural energy remains low on the list of priorities of most governments and corporate planners. Moreover, the increased demands of the more influential (and rapidly growing) urban population will make it more difficult to keep rural development on the agenda.

Unavailability of adequate energy services in rural areas is the most serious energy problem confronting humanity in the near future.

Addressing the energy needs of rural populations requires a four-pronged strategy.

- First, provide rural income-generating activities with minimally adequate amounts of improved energy services, eventually culminating in the provision of electricity services. Special emphasis needs to be placed on micro (often operated at the household level), small, and medium scale rural enterprises.
- Second, extend electricity services to dispensaries, hospitals, schools, and other rural institutions that provide critical social services, which play a key role in improving the living conditions of the rural population.
- Third, encourage households to move away from inefficient use of unprocessed solid fuels (biomass and coal) to more efficient use, with the eventual aim of shifting to modern energy forms that may potentially be derived either from renewable energy sources (biomass and solar) or from liquid and gaseous fossil fuels.
- Fourth, promote the organisation of local private sector entities into an energy market management organisation that surveys the market for local productive chains, assesses energy resources, and bridges the gap between a large number of isolated consumers and the discrete number of energy service providers and potential investors who will add value to local production. This approach of connecting demand and discrete supply reduces the transaction costs and helps develop the financial engineering required for rural consumers to generate local income.

An effective concept for thinking about the energy needs of rural populations is the "energy ladder", in which consumers "climb" from simple biomass fuels (dung, crop 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). "Climbing the energy ladder" involves not only a shift to modern fuels but often also the synergistic use of modern, more efficient end-use devices such as improved cooking stoves. The process does not necessarily mean replicating the past or climbing all the rungs previously climbed by others. In the case of cooking, for example, users do not have to go from fuelwood to kerosene to liquefied petroleum gas (LPG) or electricity. The aim should be – whenever possible – for users to leapfrog directly from fuelwood to the most efficient end-use technologies and the least polluting and affordable energy forms available (including new renewables). Because of the emergence of new technologies, it is also possible to introduce new rungs on the energy ladder, and gain even greater efficiencies and environmental soundness.

The energy-related sustainable development goals for rural areas can be derived from the Millennium Development Goals – halving extreme poverty; reducing hunger and improving access to safe drinking water; reducing child and maternal mortality and diseases; achieving universal primary education; promoting gender equality and empowerment of women; and achieving environmental sustainability. The associated energy goals are:

- Satisfying basic human needs by providing all households with minimally adequate amounts of electricity for uses such as lighting and thermal comfort (for example, through fans), in addition to cleaner cooking conditions involving better fuels and cooking devices. Specifically, all households should move away from traditional solid fuels (biomass and coal) for cooking and heating to modern energy carriers, which may potentially be derived from renewable sources (biomass and solar) or fossil fuels.
- Providing affordable electricity to support industrial activity in rural areas and thus provide employment and help curb urban migration. Both centralised (grid extension) and decentralised (stand-alone generators) rural electrification options should be evaluated.

TABLE 8. ENERGY SOURCES AND DEVICES FOR THE NEAR, MEDIUM, AND LONG TERM

Sources and tasks	Present	Near term	Medium term	Long term
Source Electricity	Grid or no electricity	Biomass-based generation Internal combustion engines coupled to generators Wind Geothermal Small hydro PV	Biomass-based generation through micro-turbines and integrated gasifier combined cycle (IGCC) turbines	Fuel cells for baseload power Solar thermal electricity
Fuels	Wood/charcoal/ dung/crop residues	Biofuels Natural gas/LPG/producer gas/biogas Vegetables oils	Biofuels Liquid petroleum gas (LPG) Synthetic gas (syngas) Dimethyl ether (DME)	Biofuels
Co-generation (combined heat and power or CHP)	Diesel engines	Internal combustion engines Turbines	Micro-turbines and IGCC turbines	
Task Cooking	Woodstoves	Improved woodstoves LPG stoves	LPG/biogas/producer gas/ natural gas/DME stoves	Fuel cells
Safe Water	Surface/ tubewell water	Filtered/treated water/ ultraviolet filtration	Safe piped/ treated water (De)centralised water treatment	Gaseous bio-fuelled stoves/ electric stoves/catalytic burners
Lighting	Oil/kerosene lamps	Electric lights	Fluorescent/compact fluorescent lamps	Ultra-safe piped/treated water
Motive Power	Human/animal powered devices	Internal combustion engines/ electric motors	Biofueled prime movers Improved motors	Fluorescent/compact fluorescent lamps
Appliances	—	Electric appliances	Efficient appliances	Biofueled prime movers Improved motors Fuel cells
Process heat	Wood/biomass	Biomass-based generation Electric furnaces Co-generation Producer gas/natural gas-fuelled/solar thermal furnaces	Induction furnaces Biofuels Solar thermal furnaces	Super-efficient appliances Biofuels Solar thermal furnaces
Transport	Animal-drawn vehicles/human-powered bicycles	Petroleum/natural gas-fuelled vehicles Compressed natural gas (CNG) and LPG	Biomass-fuelled vehicles	Fuel-cell powered vehicles

In general, the rural poor are willing and able to pay for energy services if they have appropriate financing options and they are able to meet the first costs of access and/or appliances. The economics of providing basic electricity to rural households should be evaluated according to the costs of supplying comparable energy services through less efficient carriers. In some cases, home solar photovoltaic systems can provide energy services at a lower cost than the kerosene and batteries they replace and can be an economically viable source of rural household power, even at relatively low levels of service provision.

The availability of affordable and adequate energy services in rural areas could lead to major improvements in living conditions and to the fulfilment of basic human needs in a relatively short period of time. The corresponding amount of energy needed to provide such services in rural areas is relatively small. Modern ways of using biomass more efficiently could go a long way towards achieving this objective. Experience has shown that to find the most viable and appropriate solutions to rural energy, the active participation of the people who will use it is a must.

Identifying technological options for energy sources and services depends very much on the time horizon. Starting from the existing technology, three types of technology are needed for each energy-utilising task. A near-term technology should lead to immediate improvement in 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 (Table 8).

The Transportation Challenge

Oil accounts for 97 percent of transportation energy in the industrialised countries, with natural gas (2 percent) and electricity (1 percent) accounting for the rest. The transport sector is growing faster than any other end-use sector in these countries, whose dependence on oil is one of the most daunting problems of the next decades. Growing dependence on oil is even more serious in the developing countries, where energy demand is growing three times faster than in OECD countries. In 2001, transportation accounted for 57 percent of primary oil demand in OECD countries and 39.5 percent in non-OECD countries (IEA, 2003c).

The seriousness of the problem derives from the unique characteristics of individual transportation by automobile, one of the basic characteristics of the industrialised countries, where there are 500 automobiles per 1,000 inhabitants (in the United States, it is 750 automobiles per 1,000 people). In the rest of the world, there are only 50 automobiles per 1,000 people. If industrialised-country levels of automobile ownership prevailed everywhere, the world would have 5 billion cars compared to the current 500 million cars. The consequence would be increased competition for dwindling conventional oil resources, considerably aggravated local environmental pollution, and significantly higher greenhouse gas emissions and congestion.

Attempts to face these problems have been tried along four distinct lines:

Shifting the structure of road transportation (passengers and freight) to less energy intensive transport modes, particularly public transport. In urban areas, this includes greater reliance on public transportation options, particularly bus rapid transit (BRT) and non-motorised transport (NMT). These options have the additional benefit of also being particularly advantageous forms of transport for the urban poor. The need for more urban transport interventions that directly assist the poor is demonstrated by a study in Cairo, Egypt, which found that the 10 percent of the population in the highest income group uses 54 percent of the physical space (roads and highways) dedicated to transport. In Bogota, before the BRT system was introduced, it was estimated that about 71 percent of the motorised trips were made by bus, but private cars that transport only 19 percent of the population – primarily middle- and high-income people – used 95 percent of the road space. Investments in primary roads and high-cost mass transit systems can have the perverse effect of driving out poor people as a result of escalating land and property values.

Reducing the energy intensity of various forms of travel, by improving vehicle efficiency (using less fuel per kilometre), improving utilisation (carrying more passengers or tonnes of freight per vehicle-kilometre), or improving traffic conditions so that vehicles perform better. Engine efficiency is the product of two factors: *thermal efficiency,* expressing how much of the fuel energy is converted into work to drive the engine and vehicle, and *mechanical efficiency,* the fraction of that work which is delivered by the engine to the vehicle. From a technical perspective, gains of 15 to 40 percent are possible in some of these areas.

Promoting more widespread development and use of alternative fuels to gasoline and diesel oil (in Europe, diesel is used by a third of all cars). Currently the primary fuels in use are gasoline for Otto-cycle automobiles and diesel for Diesel-cycle trucks. The primary alternatives on the horizon are:

- **Liquefied petroleum gas and compressed natural gas (CNG),** which have a higher hydrogen-to-carbon ratio than gasoline. They have a higher octane number than gasoline, permitting use of higher compression ratio engines. No major infrastructure changes are required for LPG or CNG use.
- **Biofuels,** produced from biomass, are very close to being competitive with gasoline. They come in several forms. *Biodiesel* is produced from vegetable oils and is used in France and Germany added to diesel oil. *Ethanol* is produced from sugars (particularly sugar cane) and starch by fermentation with yeasts and can be used pure or as a gasoline extender. In Brazil, where ethanol is used both as a blend of 25 percent ethanol and 75 percent gasoline and as neat ethanol (96 percent volume ethanol and

The transport sector is growing faster than any other end-use sector and dependence on oil is one of the most daunting problems.

water) in spark-ignition engines, it has replaced more than one half of the gasoline that would otherwise be used. The other large-scale ethanol user is the United States, where ethanol has been used to increase the octane rating of gasoline, to decrease carbon monoxide emissions, and more recently to replace MTBE (methyl ter-butyl ether) in reformulated gasoline. Ethanol fuel programs also exist in Kenya, Malawi, and Zimbabwe. Countries in the early stages of blending ethanol into gasoline are Australia, Canada, China, Colombia, Japan, and Thailand. In the European Union, ethanol is consumed in France, Spain, and Sweden, especially after conversion to ETBE (ethyl ter-butyl ether). Both in the United States and the European Union, the introduction of renewable fuels standards is likely to increase considerably the consumption of bio-ethanol and biodiesel. Lignocelluloses from agricultural and forest industry residues and/or the carbohydrate fraction of municipal solid waste (MSW) are a further source of biomass liquids. Although land devoted to fuel could reduce land available for food production, this is at present not a serious problem. In the longer term, lignocelluloses are likely to become the primary source of biofuels.

- **Electric vehicles using batteries** are of great interest, especially as "urban vehicles", but will probably remain as a niche market for at least a decade. If the electricity that fuels them comes from a non-fossil source, they can yield a significant reduction in greenhouse gas emission. The key barrier to their implementation is the current state of battery technology, resulting in high costs, heavy automobiles, and limited range. Large-scale introduction of electric vehicles could require major infrastructure changes, not only in the energy distribution system and the automobile itself but also in the power generation industry. However, hybrid power trains that combine an electric motor with a spark-ignition engine are already penetrating the market and provide for a suitable transition to more sustainable power trains in the long run.
- **Hydrogen** can fuel ultra-low-emission vehicles. Storage is a problem due to its low energy density. Compressed hydrogen storage is the most probable scheme, although liquid hydrogen or metal hydride storage is also possible. Today, the most probable source of large quantities of hydrogen is natural gas. In the future, hydrogen could be produced from coal or biomass, or from electricity plants using electrolysis techniques. Fuel cells offer another attractive solution because they can produce hydrogen fuel on-board the automobile by reforming methanol, ethanol, natural gas, or even gasoline, thereby avoiding the hydrogen storage problem.

Improving conversion technologies such as fuel cells or hybrids

- **Fuel cells** produce power electrochemically, rather than through the combustion processes used in conventional engines, and can potentially reach two or three times higher conversion efficiencies than today's internal combustion engine. Fuel cells come in several varieties but the proton-exchange-membrane (also called solid polymer) fuel cell is the leading candidate for automobiles because of its cost, size, simple design, and low operating temperature (< 120º C). The technology was originally used in the U.S. space program. Fuel cell vehicles are still in the development and demonstration stage and unlikely to be introduced commercially before 2010; costs for such vehicles and infrastructure are expected to be very high at least until then.
- **Hybrids** refer to vehicles having an internal combustion engine (powered by gasoline, diesel, or an alternative fuel) and an electric motor. Hybrids made their initial commercial appearance in the late 1990s, first in Japan, later in the United States, and more recently in Europe. Compared with today's conventional vehicles, hybrids are up to 80 percent more efficient.

Policies to reduce the growth of automobile use and freight transportation by road have been rather unsuccessful so far for a number of reasons, including lack of public support, the inelastic response of the transport sector to energy price increases (i.e., drivers do not drive less even with higher fuel prices), and the very slow turnover of transportation infrastructure.

Taking energy into consideration in land-use planning, and in designing physical infrastructure, construction standards, and transportation systems, can reduce some

> *A low-carbon future is fully consistent with rising living standards in the industrial countries and with economic prosperity in developing countries.*

of the growth in energy demand that accompanies rapid urbanisation. Transportation systems may be especially important, given the rapid growth in the number of motor vehicles world-wide. At current rates of growth more than one billion cars are likely to be on the road by 2020. Most of the additional cars will be driven in the cities of the developing world, where they will create more congestion, aggravate urban pollution, and undermine human health – even with optimistic projections about efficiency improvements and alternative fuels. Eventually they are likely to spread out, much as has been occurring in many industrialised countries, to swamp rural areas with road infrastructure and loss of countryside.

Only long-term changes in habits and consumer preferences – reflecting demographic changes, environmental awareness, changes in lifestyles, and higher energy prices – could alter this projection. Government policies can play a crucial role in facilitating such a transition by creating incentives or taxes that reflect the full cycle cost, including externalities of the various alternatives. Successful measures adopted in the central part of London – which basically charges automobile drivers for the use of streets – reduced congestion and almost doubled average speed. Along the same lines are proposals to improve traffic conditions during peak traffic times by promoting carpooling or co-ordinating traffic lights to create "green waves" of easily moving traffic.

Energy and Economic Prosperity

In the industrialised and transitional economies, demand for the services provided by energy – heat, light, motive power, transport, and so forth – continues to grow. However, improvements in the efficiency of energy conversion and use are likely to result in a levelling off – and, over the long term, in a decline – in these countries' demand for primary energy. In developing countries, in contrast, primary energy demands are expected to grow at about 2.5 percent per year for several decades, as productivity and living standards improve and as more people have access to modern energy for the first time. Developing countries' current per capita consumption of commercial energy is less than one fifth that of the industrialised countries, and their populations will be nearly ten times larger than industrialised countries in two generations. In any scenario of economic success, world energy demands are thus set to rise significantly in the coming decades, even allowing for improvements in energy efficiency. In the middle of the next decade, energy use in industrialised countries will be surpassed by consumption in the developing countries, exacerbating competition for fossil fuels.

Meeting the energy demands of developing countries will be essential if they are to achieve economic prosperity, and will require considerable investment. It is estimated that annual investments on the order of 2 to 2.5 percent of GDP, presently corresponding to $150 to $200 billion per year, will take place in the developing countries over the next two decades alone. This level of investment is close to historical norms and, with good financial and economic policies, should be affordable.

In the past, investments in the energy sector in developing countries rested heavily – and unnecessarily – on government subsidy, and too little on the financial resources that would be generated by regulatory policies to encourage managerial efficiency and prices that reflect actual costs. However, there is no reason why the energy sector should not be financially self-sufficient. Regulatory policies to encourage cost-reflecting prices would raise sufficient revenues to cover operating costs and generate good returns to investment, and thus attract private finance and investment on a large scale. One of the primary aims of market liberalisation and the new forms of regulation introduced in many countries in the 1990s was precisely this: to reduce the need for government subvention and to attract private capital and investment into the industry. The other aims were to encourage innovation and managerial efficiency.

The regulatory framework also needs to give priority to the task of extending energy services to unserved populations in rural and urban areas. If development succeeds and universal energy service is provided, an additional five to six billion energy consumers will be added over the next fifty years. This is in principle achievable, as demonstrated by the 800 million people to whom electricity service was extended in the period 1970-1990. In fact, under more favourable new regulatory frameworks, more rather than fewer financial resources should become available, motivated by the prospects of higher returns on investment.

However, a disturbing trend of the privatisation programmes of the 1990s is that in many countries the goal of service extension has receded from the regulators' responsibilities. There is a danger that, unless service extension receives priority, privatisation programmes, for all their merits, will come under attack and be delayed so much that what they promise to accomplish will not be done. Service extension does not mean necessarily an extension of electricity grids; in many cases, local solutions such as wind and solar energy can provide the services needed.

Inaccessibility of commercial energy cannot be fully eliminated over the foreseeable time horizon, but it can be significantly reduced. Accessibility needs to be continually improved each year, in percentage terms and in absolute numbers. The two billion people currently without access to commercial energy are increasing at the rate of almost 30 million per year. Correspondingly, service expansion has to surpass this figure by a reasonable margin; each year at least 40 million new people need to be supplied with energy services if the number of people without service is to be reduced. This means providing electricity plus fuels such as liquefied petroleum gas for cooking to at least six million new homes annually. The investment required to achieve this will be around $10 billion per year. This is a small amount that does not exceed 5 percent of global annual energy investment; it is less than 20 percent of global official development assistance. However, it is still beyond the capability of most low-income developing countries.

Although total energy resources are available to meet the expected expansion of demands, the much-discussed environmental problems arising from energy production and use must also be addressed. One urgent issue is local pollution, currently increasing in developing countries in direct proportion to increased energy use. The same thing happened historically in the industrial countries until roughly the last third of the twentieth century, when new low-polluting technologies were developed and brought into use under the stimulus of environmental regulation, enabling local pollution to be greatly reduced even as energy demands continued to rise. Developing countries have the opportunity to adapt and incorporate these technological advances at an earlier stage of development than the industrialised countries. All the evidence shows that the costs of abating local pollution are far outweighed by the benefits.

By addressing the negative externalities of energy generation and use early on, developing countries would find the overall economic well being and prospects of their people improved, not diminished. Rational energy pricing is part of what is needed, but so is a willingness to prompt markets to adopt available technologies and practices to reduce the serious costs of local pollution. There is now a wealth of information and experience to draw on to define an appropriate regulatory framework for the production and use of energy in environmentally more satisfactory ways.

Another urgent issue is climate change. Three insights have emerged from the numerous studies of technology responses to climate change over the past decade.[16]

- Technologies are emerging to support a low carbon energy future, particularly in the fields of efficiency improvements, renewable energy, hydrogen production from fossil fuels and non-carbon sources, and carbon sequestration. It can now be said with reasonable confidence that a low carbon future is technologically feasible, although the transition to such a future will take some time.
- There is immense scope for innovation; costs of new technologies for efficiency and renewables are declining and are unlikely to be much higher than fossil fuel costs, and in some cases lower.
- The transition to a low-carbon economy would have little or no adverse impact on the economic prospects of either the developing or the industrialised countries. In fact, a low-carbon future is fully consistent with rising living standards in the industrial countries and with the goal of developing countries to achieve economic prosperity (Box 5).

What is now needed is a set of policies to stimulate the development and use of low-carbon technologies and practices. Such policies are being put in place at the national level in a number of industrialised and developing countries, e.g., in the form of support programmes for renewable energy, energy efficiency, hydrogen-linked technologies such as fuel cells, and carbon dioxide capture and storage. Most, however, are still tentative and in their early phases (barely a decade old); a number of countries are currently reworking their approaches based on this early experience and the new evidence on climate change put out by the IPCC.

16. Major studies include reports by the IPCC, international agencies such as the Global Environment Facility, several industry studies, and the report of the G8 Task Force on Renewable Energy; they are winning acceptance, most recently during the World Summit on Sustainable Development in Johannesburg.

BOX 5. CAN THE WORLD AFFORD TO MOVE TO A LOW-CARBON ENERGY ECONOMY?

The annual expenditures of meeting the world's current primary energy requirements are enormous – around $1 trillion per year, plus perhaps a further $2 trillion per year to provide the supporting infrastructure and services (for example, electricity generation, transmission, and distribution networks; coal mining and distribution networks; gas grids; and oil refining and marketing infrastructure). Such infrastructure investments have made the achievement of economic prosperity possible in the rich countries, and hold the same promise for the developing countries. Is it, therefore, too risky, from an economic viewpoint, to seek to reduce the energy system's dependence on fossil fuels over the long-term in the interests of addressing environmental problems and achieving sustainable development?

Available studies show that the costs of investment in alternatives will not be prohibitive – and indeed may be negative, that is, economies will be better off making these investments, not worse, in the long-term. The reasons:

- Alternatives to fossil fuels are available and abundant, sufficient to meet human energy needs in perpetuity.
- Their costs are not far removed from those of fossil fuels, and in some cases are lower.
- Costs are declining over time with innovation and investment.
- Improvements in the efficiency with which energy is converted and used are leading to cost savings and reduced waste, and are often more than sufficient to offset the extra costs of non-carbon supplies.

Economic studies have consistently put the added costs in the range of minus 1 to plus 2 percent of gross world product over a fifty-year period, during which time world product should rise by 300 to 500 percent in any scenario of economic success. In other words, at worst, investing in non-carbon sources of energy may shave a few months' growth of output off during the fifty-year period, but may even add to output.

Even this conclusion is too pessimistic:

- Such calculations ignore the environmental benefits, both local and global, that numerous studies have concluded can considerably outweigh the costs of pollution abatement by turning to "clean" technologies.
- The scope for reducing economic losses ("deadweight losses") through price reforms and liberalising energy markets is enormous.

Taking these factors into account, the evidence is compelling that both the developing and the rich countries will be economically better off with a transition to energy-efficient, low-carbon economies.

Source: M. Grubb, R. Koehler, and D. Anderson, The Annual Review of Energy and Environment *27, pp. 271–308 (2002).*

It will be important, at the international level, for countries to share experiences in their efforts to define ways forward.

Also needed is additional support to foster innovation and co-operation in the development and use of non-carbon technologies. The Global Environment Facility has helped set the scene by providing finance for proven non-carbon technologies and practices, and has a successful portfolio of projects in over seventy countries; it is also doing much to foster policies that would support market development. Ideally, the Facility needs to be complemented by a parallel initiative to foster international co-operation, innovation, and the commercialisation of advanced non-carbon energy technologies.

Since most of the growth in energy demand will be in developing countries, joint mobilisation of official development assistance from developed countries and international institutions is a must if the aim is a global sustainable future. By adopting the Equator Principles, the private financial community has taken steps to ensure that projects financed by banks are consistent with the environmental and social screening criteria and safeguard policies of the International Finance Corporation and with World Bank guidelines (e.g., on coal mining and production, wind energy conversion systems, and the environment in general).

The banks agree not to provide loans directly to projects in which the borrower is unable to comply with their environmental and social policies and processes. They furthermore agree to require an environmental assessment that includes information on baseline environmental and social conditions, protection of human health, cultural heritage, biodiversity including protection of species and sensitive ecosystems, sustainable development, and use of renewable natural resources.

The Equator Principles apply only to projects costing US$50 million or more, on the grounds that projects below US$50 million only account for 3 percent of the project financing loans market. Many critics argue that the exclusion of lower-cost projects is a major shortcoming of the Equator Principles. They argue that the framework fails to address precisely the projects that can most help the poor in many developing countries, and that participating banks should be encouraged to lower the cut-off point for applying the Principles and to finance more low-cost schemes. ■