FUTURE SCOPE AND STRATEGIES IN ENERGY EDUCATION

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ABSTRACT

This paper identifies the scope and strategies in energy education related to Mechanical Engineering. The global and local trends in energy sources, technologies and social & environmental aspects with reference to standard scenarios have been identified. This information together with the current status of energy education in the country has been utilized to establish the scope and strategies for the future energy education at tertiary level based on two time horizons: short term and long term that are mainly dominated by trends, policies and conditions in global and local contexts respectively.

ENERGY AND SUSTAINABLE DEVELOPMENT

There exist certain involvement of some form of energy in all activities in nature. In fact, life is a continuous process of energy conversions and transformations. Ever since the mankind's evolution, energy has been the prime vector of human society. Interaction of energy and human society has indented many milestones in human civilization, starting from discovery of fire, invention of the wheel, steam engine, discovery of electricity, internal combustion engine, nuclear fission and fusion, to propelling of space vehicle to conquer the space. Such achievements were greatly influenced by the availability of affordable energy in ample quantities. Moreover, harnessing of different forms of energy in order to extend human capabilities has led to accomplishments of all civilizations. In essence, science and technology developments fuelled by energy have enabled to satisfy basic human needs, improving social welfare and achieving economic development.

However, the development of the energy sector has resulted in many effects that endanger the quality of life of current and future generations and carrying capacity of ecosystems. Even though the natural forms of energy sources are inert, their extraction, conversion to more useful forms and usage always generate undesirable by-products and emissions that result in environmental problems at every scale (i.e. from the health impacts of wood smokes in rural households to the disruption of global climate by emission of greenhouse gases), irrespective of whether the source is fossil, mineral or renewable. For instance, the combustion of fossil fuels is responsible for most urban air pollution, regional acidification and risks of human induced climate change. The use of nuclear power has created a number of concerns about the safety of nuclear installations, the storage and disposal of high-level radioactive waste and the procreation of nuclear weapons. The manufacturing of photovoltaic panels generates toxic waste. In some cases, the use of biomass contributes to desertification and bio-diversity losses.

From the perspective of society, the more important element is not energy but energy services such as cooking, lighting, transportation, comfortable indoor climate, etc. Energy services are the result of a combination of technology, infrastructure (capital), labour (know-how), materials and energy carriers. The demand for energy services is the driving factor of the structure and size of an energy system. Energy services, in turn, are determined by large number of driving forces including: Economic aspects (economic structure, economic activity, income levels, market conditions, etc.); Demographics (population, degree of urbanization, etc.); Geography; Technology base (age of existing infrastructure, level of innovation, access to research & development, technical skills, technology diffusion, etc.); Social aspects (lifestyles, individual and social preferences, cultural moves, etc.); Policy factors (that influence economic trends, energy, the environment, subsidies and social welfare); Laws, institutions and regulations. From the perspective of consumers, the important issues are the economic value or utility derived from services.

The technology is the underlining factor, which determines the quality of the energy service, its affordability and environmental compatibility. Modern energy systems rely on processed or manufactured fuels and sophisticated conversion equipment resulting cleaner and efficient energy product or service. On the other hand, traditional energy systems involve technologies with low efficiencies and high levels of pollution. The technology is more than a power plant or an air-conditioner or a vehicle. It includes infrastructure such as building, roads and transportation system, and industrial plant & equipment. It also includes social and cultural preferences as well as law and regulation that reflects compatibility of technology options with social & political preferences, compatibility and cultural background. In fact, energy attracts the widespread attention of public and their political leaders mainly in times of short-run supply-price "crises", despite its vital importance to the human condition. One example is the present electricity fiasco in Sri Lanka.

The factors discussed above indicate the undeniable necessity for utilization of energy in a rationale manner without overloading the carrying capacity of ecosystem and depriving the ingenuity of the future generation. The whole world faces a daunting array of energy related challenges, which would be decisive factors in sustainable economic and industrial growth and technological innovations. In fact, sustainable development with a minimum environmental degradation has become the motto of energy engineering. The importance of these aspects has received a new momentum in the recent past with the concerns & mechanisms originated by international level activities such as ISO14000 on environmental aspects in the industrial sector, Montreal protocol and Kyoto protocol in relation to climate change. In particular, Kyoto protocol specifies green house gas (GHG) emission reduction requirements and include clean development mechanisms (CDM) for GHG emission reduction projects.

Therefore the energy sector should never be analyzed in isolation but with interrelation to environment and society. For such analysis, a sound knowledge on all the related areas and associated skills are vital not only for technical aspects of energy but also for managing, advising and policy making in the sector, through well structured and planned educational framework.

Taking these facts into consideration, this paper intends to analyze the energy scenarios which explore the future trends in the energy domain, present the current status of the energy education, and identify the scope and strategies of future energy related educational activities.

ENERGY SCENARIOS

History

Over the time, changes in the use of energy have been taken place and will continue to do so, with regard to the amount as well as the source types. Many factors have played a role in bringing these changes. Availability, security of supply, prices, ease of handling and use, external factors such as technological development, introduction of subsidies, environmental constraints and legislation are some of these factors. The review of the history of energy use indicates three distinct periods characterized by different dominant sources: wood and other traditional sources in pre 1850, coal in 1850 to 1920, and oil and gas in post 1920 to date. At present the world energy use by source is approximately coal - 22%, oil - 30%, natural gas - 23%, nuclear - 6% and renewable (including biomass, hydro, geothermal, wind, solar, etc.) - 19% (World Watch Institute 1999). However, in developing countries, contribution of fossil fuel in the primary energy use is much lower and renewable such as biomass dominates.

Energy use from 1970's onwards has been influenced by various factors. Of which, the oil crisis in 1970's and 1980's probably have had a marked influence, not only on energy use but also on developments in the energy sector. Many countries switched from oil to other sources such as coal, natural gas, nuclear energy, etc. Besides, extensive research and development activities were undertaken to develop and promote alternative sources, in particular renewable energy sources such as wind, solar, geothermal, biomass, etc. Further, effect of increase in oil prices was the onset of energy conservation activities in many countries, especially in industrial and domestic sectors. Another main factor which has influenced the energy use and related developments in the recent past, and will remain valid in the future, is health and environment impact of use of fossil fuel. This has forced the world in the direction of cleaner energy systems and/or sources. This reality has a pronounced influence on predicting the trends in future energy use and related impacts. Prediction of such changes is wrought with uncertainties. In 1900, no one predicted that oil would become a major source of energy!

Global Trends in Energy Sector

There are many sustainable energy scenarios developed by various organizations (Morita and Lee 1998). These predictions show large variations in the importance of the various sources of energy depending on what view is taken with regard to the use of fossil fuels, the acceptability of nuclear energy and renewable energy technology developments. Besides these, population growth, economic development, improvements in energy conversion efficiencies, environmental considerations are some of the other factors that have influenced the outcomes of these predictions.

Energy scenarios provide framework for exploring future energy perspectives that take into account different technological options and resulting social and environmental implications. These scenarios deal through different energy system developments with varying degree of sustainability. Using strong assumptions, they prescribe desirable futures and how such futures can be achieved. As these achievements require fundamental change or major paradigm, most of them cannot be realized with current policies and prevailing development trends. Thus sustainable energy scenarios are often designed to offer policy guidance on managing an orderly transition from present energy system towards a more sustainable system.

In order to identify the scope of future energy related educational activities, a set of energy scenarios developed by International Institute for Applied Systems Analysis (IIASA) and World Energy Council (WEC), which has received a wide attention, is selected in the present study (Nakicenovic at al. 1998). There are three cases, designated as A, B and C, which are unfolded into six scenarios of energy system alternatives. Case A includes three variant scenarios (i.e. A1, A2 and A3) and reflects a high-growth future of vigorous economic development and rapid technological improvements. Case B represents a middle course, with intermediate economic growth and more modest technological improvements. Case C includes two variant scenarios (C1 and C2), which are ecologically driven. It incorporates challenging environmental and energy taxes to protect the environment and to transfer wealth from North to South to enhance economic equity. This approach leads to lower energy use but high overall growth. Figure 1 shows the range of future primary energy requirement for the three IIASA-WEC cases.

The roles of different primary energy sources vary across the different scenarios. Some continues to be fossil fuel intensive, while others show stronger shifts towards alternative sources such as renewables or nuclear. Figure 2 illustrates this long-term divergence in the structure of energy systems across the six IIASA-WEC scenarios. The figure also shows the historical shift from renewable (biomass) sources in 1850's to coal in 1920's and to oil and gas in the recent past.

The IIASA-WEC scenarios also indicate the areas of technological opportunities related to energy related activities with corresponding global market potential. The related technologies are classified into four groups: New end-use devices, Power plants, Synfuel production and energy transport, transmission and distribution infrastructure. Figure 3 illustrates the global market potential for these four groups under the six energy scenarios in 2020 and 2050.

Local Trends in Energy Sector

In Sri Lanka, as in other developing countries, the major source of primary energy supply has been biomass. At present the share of biomass is about 51% and that of other sources are fossil fuel - 37% and hydro - 12% (ECF 2000). In the past, the electricity generation of Sri Lanka is dominated by hydroelectricity. As most of the economical hydro power potential has already been harnessed, more and more thermal power plants have been added to the generation system to cater the ever increasing demand for electrical energy. In 1999, the total installed capacity of electricity generation is approximately 1691 MW, which comprises of 1143 MW Hydro (68%), 545 MW Thermal (32%) and 3 MW Wind (0.2%) (CEB 2000).

Therefore, the contribution from thermal sources becomes increasingly important. Especially, the long-term electricity generation plan of Ceylon Electricity Board (CEB) is almost entirely depends on thermal options, mainly coal based. In the generation plan repaired by CEB the total capacity addition by the year 2013 is 2190 MW and 90% of that is from thermal power plants, mainly coal based (1200 MW of coal power plants). The capacity additions by the plant type are presented in Table 1 (CEB 1999).

Table 1: Capacity additions by plant type

Type of Plant	Plant Capacity (MW)			Total	
	1999-2003	2004-2008	2009-2013	MW	%
Hydro	70	150	-	220	10
Combined Cycle	450	-	-	450	21
Coal	-	600	600	1200	55
Gas Turbine	-	-	210	210	10
Diesel	100	-	10	110	5
Total	**620**	**750**	**820**	**2190**	**100**

Source: CEB (1999)

In synthesizing the above global and local trends in energy related activities, the scope for energy education highlighting the sectors covering sources, technologies and environmental factors could be identified.

ENERGY EDUCATION

Engineering differs from science in terms of its specific characteristics of the method, focus, practice, representation and tools used. Engineering relies on synthesis and holistic methods, focusing on experience and knowledge, practicing through realization, representation by models, using artificial intelligence as a tool. In contrary, science relies on analysis focusing on theories, practicing through generalization and representing by theory in terms of mathematical tools. Engineering education should take these distinct differences into account in formulating its framework.

The role of the Tertiary education can be viewed as developing a product and/or service to the local and international market. Such products of the education should possess the adequate knowledge, skills of application and research capabilities. In catering to the above mentioned basic characteristics of Engineering and the interrelated nature of the domain of energy, the education in this domain should posses a multi-disciplinary nature.

As the core of energy engineering consists of energy sources and associated technologies, Mechanical Engineering is the leading stakeholder in energy education. In fact, energy has become a major subject area of specialization in the Mechanical Engineering field. However, a very little prominence has been given to the energy education even at the tertiary level, until recently. Therefore, it is important to review the present energy education and identify scope and strategies for the future.

Present Status of Energy Education

The present status of the activities related to energy education in Sri Lanka can be reviewed under the following categories representing different levels in the education system namely, primary, secondary and tertiary.

The majority of primary & secondary schools in Sri Lanka come under the purview of the Ministry of Education and Higher Education. In addition, there are few private schools, which implement the same curriculum as that of the state schools. There are also few International schools that work on a different curriculum more in line with foreign examinations.

In the state school curriculum special lessons/chapters are included in order to introduce the energy sources and their applications and highlight their importance in relation to environmental issues. The areas covered include applications such as wind mills, water wheels for developing work, photovoltaic panels, hydro-turbines for generating electricity, solar thermal for cooking are illustrated and in some instances demonstrated using simple models. Further, indication of water and air pollution due to the use of fossil fuels is highlighted. These have been included into the curriculum in the recent past by the Ministry of Education.

At tertiary level energy education is primarily carried out in University curricula in the purview of undergraduate and postgraduate studies. Almost all the Universities, except for one or two privately owned institutes, come within the purview of the Ministry of Education and Higher Education. There are three Faculties of Engineering in the Sri Lankan university system. These three Faculties are established within the

University of Moratuwa, University of Peradeniya and University of Ruhuna.

In the University of Moratuwa, topics on energy are offered in the B.Sc Engineering Degree programme mainly in the final year optional subjects in Chemical Engineering, Mechanical Engineering and Electrical Engineering Departments. However, some fundamental topics on energy are introduced at early stages of the Chemical Engineering curriculum.

In the Mechanical stream energy topics are offered within the subject of *Energy Engineering* since 1995. The main areas covered are, Sources: fossil and Renewables, Conversion technologies, Energy conservation and management, Economic evaluation of projects. Practical aspects and applications of these are covered through the Undergraduate projects as partial fulfilment of the Degree programme.

The Department of Agriculture Engineering at the University of Ruhuna has recently introduced a three day short course on renewable energy systems as a part of undergraduate curriculum covering applications of solar, biomass, wind and micro-hydro.

At present the faculty of engineering at the University of Peradeniya offers an optional final year course on energy systems covering only energy conservation and management.

The department of Mechanical Engineering of the University of Moratuwa commenced the first ever postgraduate programme in Energy Technology in Sri Lanka in October 1999. This programme, which is structured for an intake of about 20 students, awards a Postgraduate Diploma for completing the course work requirement (one year) or the Degree of Master of Engineering upon the completion of a suitable research project. The total duration is two years. The programme offers a course modules on energy sources, transfer process, industrial fluid dynamics, mathematical techniques applicable to analysis of energy systems, fuels and combustion, energy conservation and management, energy economics, design of energy systems, instrumentation and experimental techniques, waste heat recovery, boiler and furnaces, building energy and energy & environment.

The Master of Engineering projects in the second year of the postgraduate programme are based mainly on research & development activities related to local energy sector. They are expected to cover research aspects of energy systems rather than product development objectives of those in the undergraduate programme.

Postgraduate programme in Electrical Engineering also offers a PG Diploma/Masters in Electrical Engineering where some aspects in energy sector are covered through modules on Energy Economics, Rural Energy Systems, Feasibility Analysis of Micro-hydro, Wind and Solar systems.

This review of the present energy education reveals that an attempt is made to impart a reasonable amount of knowledge on the core subjects but none of these provide adequate opportunities to develop the skills of applications.

SCOPE AND STRATEGIES FOR THE FUTURE

Scope for energy education in the future at tertiary level is established based on two time horizons: short term and long term. The analysis of the long term is mainly dominated by global trends, policies and conditions while that of short term is dominated by local trends, policies and conditions.

In the case of short term, the local trends in the energy sector for large scale power generation indicate a mix of energy sources dominated by fossil fuels, choice of which is influenced by many factors such as the market prices, price trends and availability of sources. However, the pressure resulting from environmental and social factors has directed this choice towards relatively expensive but cleaner gaseous fuels, as observed in global level. This has in consequence resulted in envisaging more efficient and cleaner technologies. Such technologies are the subject of many global research and development activities in the recent past, most of which involves turning the coal to gas, and using a gas turbine. Examples of this type of plants include the pressurized fluidized bed combined cycle (PFBC), the integrated gasification combined cycle (IGCC) and topping cycles. With reference to these, the scope should encompass the aspect of strengthening the knowledge rather than strengthening skills of applications and research of these emerging technologies. The strategy should be dissemination of such knowledge primarily through undergraduate studies in the mechanical engineering curriculum followed by relevant CPD course.

In addition, medium scale grid connected power generation and stand-alone systems for rural electrification will play a vital role. For example, small hydros, stand-alone solar PV and wind systems, and contentious biomass based systems are some of the relevant candidates. Such energy systems have already begun its penetration to the local energy sector especially in rural areas where there is no easy access to the national grid, through different energy programmes introduced by both governmental and non-governmental organizations. Although programmes to transfer the skills required for operation and maintenance aspects and research & development activities of such energy systems are present in the country, there is a need for further strengthening skills of application and imparting the knowledge and relevant research & development activities. Especially focusing on innovation & optimization and management strategies, economic analysis, pre and post environmental and social impact analysis. Further, as most of the commercial and industrial energy systems are not competitive with the state of the art efficiencies and standards, the energy conservation measures and rationale utilization techniques could play an important role as an invisible energy source. In this regard, imparting knowledge by strengthening of the undergraduate and postgraduate curricula, through undergraduate projects and postgraduate research projects are strategies to improve the quality of products from the university. Further, demonstration of commercialized technologies through working models and pilot plants is also a strategy for effective education. On the other hand carrying out consultancy and workshops to impart knowledge and transfer the skills of application could be strategies to improve the services. In essence this enables our products and services to cater the future innovations and provide the background to foster the attainment of Research & Development targets related to the Energy sector.

As for long term, the global trends under IIASA-WEC energy scenarios indicate a mix of energy sources and associated technologies having a wider spectrum. Some of the scenarios continue to be fossil fuel intensive, while others envisage shifts towards alternative sources including renewables, nuclear and emerging sources and technologies such as synfuel/hydrogen-based ones. Such emerging sources have already started successful penetration to the energy sector in the region. For example, hydrogen as an energy carrier, fuel cells as technology with high efficiency and near zero air pollutant emission have receive intense attention if the transport sector. The global trends in the long term will have a significant influence on the future planning in the energy sector, policy instruments and other related activities in the country. This brings into focus that on long-term perspectives, wider range of sources and technologies will have to be envisaged in developing educational framework. These sources and associated advanced technologies are relatively new to the present scope of the energy education in the country and not yet envisaged to a satisfactory extent. The identified scope indicates that the strategy of energy education should be imparting the knowledge and conducting appropriate research at the postgraduate level while transfer of skills of application to be planned through CPD courses.

Another important aspect to be considered in developing the scope and strategies of the energy education in the country is energy related activities in the region. The regional activities have generated scope for active participation. Building the capacity and competence of the products through effective participation in the related activities at the university level is the strategy. One such activity recently originated is CDM in the Kyoto protocol which involves the participation of both developed and developing countries through project based activities in achieving sustainable development.

CONCLUSION

The role of the Tertiary education can be viewed as developing a product and/or service capable of catering the current and future needs of the industry. Such products of the education should possess a cyclic relation of the knowledge base (of principles), skills of application and research capabilities. In catering to the basic characteristics of Engineering and the interrelated nature of the domain of energy, the education in this domain should posses a multi-disciplinary nature.

The present energy education framework has made attempts to impart a reasonable amount of knowledge on the core subjects of energy but none of these provide adequate opportunities to develop the skills of applications to bridge the gap between the university and the industry in this domain.

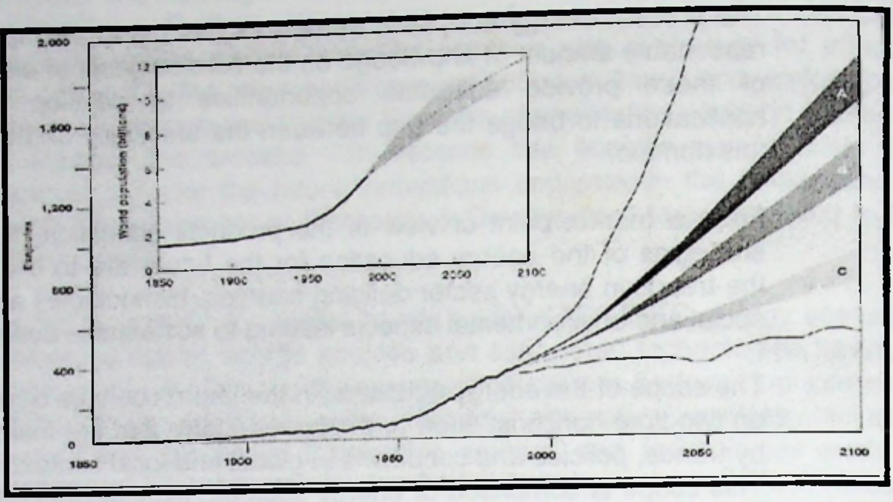
From a market point of view of the products education, the scope and strategies of the energy education for the future are to characterized by the trends in energy sector defining sources, technologies and associated social and environmental aspects leading to sustainable development.

The scope of the energy education in the future could be developed based on two time horizons: short term and long term that are mainly dominated by trends, policies and conditions in global and local contexts respectively. This scope is comprised of energy sources, technologies and associated social and environmental aspects. This essentially includes the shift in the fuel mix, reliance on advanced and emerging technologies and promoting cleaner fuels.

The strategies of the energy education are to be developed in satisfying the key characteristics of products i.e. knowledge, skills of application and research. This requires a vertical disintegration of the education in tertiary level, into postgraduate, undergraduate & continuing professional developments, and technical levels.

The education in PG level is to be planned with reference to synthesis of trends in sources, technologies and relevant environmental and social aspects on a long-term time horizon. These issues are to be analyzed distinctly in depth and subsequently their interrelations. Moreover, emphasis on economic and policy issues should be incorporated. The research activities and detailed design aspects of energy systems should be undertaken at postgraduate level through Master of Engineering project activities. The knowledge and experience of these should flow downwards to undergraduate and technician levels.

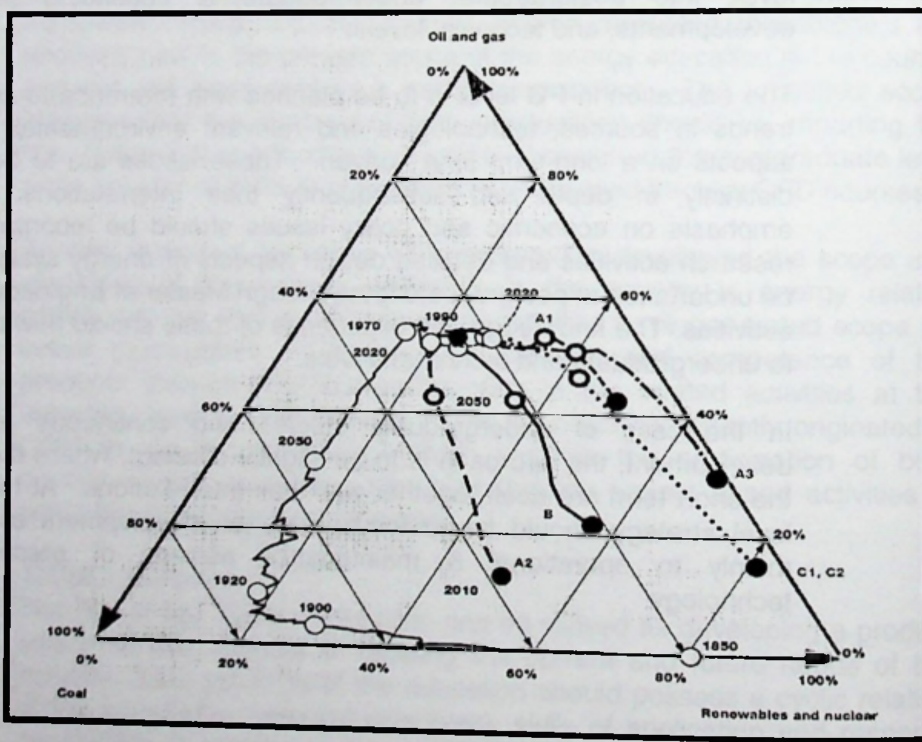
In the case of undergraduate studies and continuous professional development, the approach is to be slightly different, where the issues in the short term are dealt together with their interrelations. At the technical level strategy should be to focus more on development skills related mainly to operational & maintenance aspects of present energy technology.



Source: Nakicenovic at al. (1998).

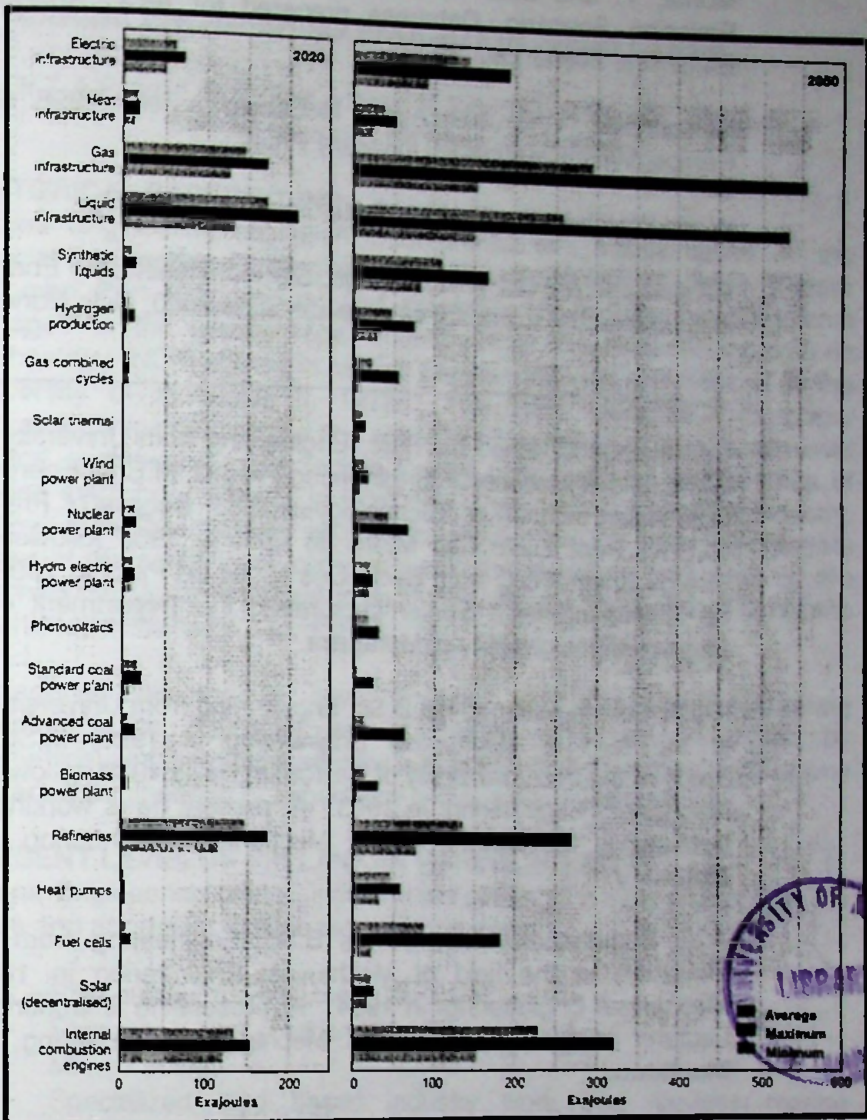
Note: The insert shows global population growth till 2000 and projections to 2100. The figure also shows the wide range of future energy requirements for other scenarios in the literature.

Figure 1: Global primary energy requirements during 1850-1990 and in three IIASA-WEC cases from 1990 - 2100.



Source: Nakicenovic at al. (1998).

Figure 2: Evolution of primary energy structure: Share of oil & gas, coal and non-fossil sources(renewable and nuclear) during 1850-2000 and in three IIASA-WEC cases from 2000 - 2100.



Source: Nakicenovic at al. (1998).

Figure 3: Global market potentials for different classes of energy technologies

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