THE DEVELOPMENT OF TECHNOLOGIES DESIGNED TO INCREASE ENERGY EFFICIENCY

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1. Introduction

In recent years there has been a growing concern for more efficient use of energy in view of its increasing world consumption and the realization that fossil fuel resources, particularly the premium fuels – oil and gas – are being depleted rapidly. This concern appears quite justified if one looks at the growth of world consumption of energy over the last one hundred years (*Figure 1*). With the exception of some crisis periods, the consumption of primary energy in the world has been increasing exponentially at an average growth rate of about 5 % per year. Most of the growth so far may be attributed to the increasing energy demand by the present developed regions in the process of their industrialization and relatively fast economic growth. In 1975 world consumption of primary energy was about 8 Tirawatts (TW or 10^{12} Watts) of which the share of the developing regions (comprising about 70 % of the world population) was only about 16 %. Now as the developing regions undergo a process of industrialization they too will require a rapid increase in their energy consumption, much faster than the rate of their population growth, while the industrialized regions will also need more energy just to sustain their economic growth or even to avoid stagnation and depression. Will such a growth continue in the foreseeable future or can it be arrested through technological developments and conservation measures at a level not much higher than the current level without serious repercussions on economic development and human welfare? To answer these questions one needs to understand the nature of energy demand, the potential of technological developments for improving the efficiency of energy use and the possible impact of conservation measures in different regions of the world.

Figure 2 shows the variations of primary energy consumption per unit of GDP in the US economy during the period 1885 - 1975. Until 1915 the curve shows a rapid increase in the ratio of energy consumption to GDP, and is associated with the process of industrialization in the USA following the industrial revolution. The decrease in the ratio from 1915 onwards may be partly accounted for in terms of structural changes in the economy – giving more emphasis to services – but is mainly due to the incorporation of heavy machinery, better processes, sophisticated products and improved skill.

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C. T. Saunders (ed.), *East and West in the Energy Squeeze*

The figure thus shows that there exists a complex interplay between the economy and the factors such as energy, capital, know-how and labour, which are all driving elements of an economy. Different regions of the world will therefore have markedly different paths for growth of energy consumption depending on the stage of their development, composition of their economic infrastructure and the extent to which the various factors driving the economy may be brought to play against one another in different socio-economic environments.

2. Energy and Economy

To get a better appreciation of how energy is used in the economy one may look at the energy flow diagram of *Figure 3*; this also seeks to clarify the terms primary, secondary, final and useful energy which are used to characterize different forms of energy. The term primary energy refers only to the resource consumption e.g. of fossil fuels and uranium extracted through mining. Conversion processes such as refinement of crude oil to gasoline or generation of electricity transform the raw primary energy to more usable forms - secondary energy - but only at the expense of conversion losses diverted to waste heat which, in the particular case of electricity generation, amount to as much as two-thirds of the primary energy input. Then there are some transmission and distribution losses before the end user gets his requirements in the form of final energy. Local conversion devices such as ovens, automobiles and lamps provide useful energy as process heat, mechanical motion, light, etc., while a substantial fraction of the final energy is diverted once more to waste heat. How large are these losses as a whole? For a modern economy they may amount to approximately two-thirds of the primary energy input (3), so that, in terms of heat content, only about one third of the primary energy appears as useful energy. But the useful energy is not consumed either. It is simply a means of providing energy services such as the generation of value added in industry, the transportation of people and goods, the provision of human comforts, etc.; and having done so it too ends up as waste heat.

The energy services are provided by a combination of useful energy, capital and labour, i.e. skill and know-how, and there exists a considerable possibility of substitution between these elements. Consider, for instance, a potter who produces pottery using a turn-table and a set of tools as his capital investment. The amount of energy consumed per unit of output (value added) depends on the quality of his investment as well as on his skill and mental image of the pottery. As his skill and perception improve he is able to produce more and even better quality of pottery (more value added) while still using the same amount of energy. He may then further reduce the ratio of value added to energy input by using more capital, e.g. by changing over to better quality turn-table and tools. Another example from everyday life we may use to illustrate the point is that of a warm room. The amount of heat input necessary to keep the room at a comfortable temperature may be reduced by improving the insulation, which requires more investment, and by keeping the doors and windows closed, i.e. through more care and effort.