Topics in Energy

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Energy Demand: Facts and Trends

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Table of Conversion

1 MJ = 10^6 J = 239 kcal = 0.278 kWh
1 GJ = 10^9 J = 278 kWh
1 TJ = 10^{12} J = 0.278 Gwh = 23.9 toe
1 PJ = 10^{15} J = 0.278 TWh = 0.0239 Mtoe
1 EXJ = 10^{18} J = 23.9 Mtoe = 278 TWh

1 kWh = 3600 kJ
1 kcal = 4186 J
1 Gcal = 10^6 kcal = 4.18 GJ
1 toe = 41.8 GJ
1 BTU = 1055 J = 0.252 kcal

1 Mtce = 29.3 PJ
1 Mtoe = 41.8 PJ
1 Mboe = 38.7 Mtoe = 1620 PJ
1 TWh = 3.6 PJ
1 QUAD = 1.055 EXJ = 25.2 Mtoe (= 10^{15} BTU)

Introduction

Towards the close of 1973, the four-fold increase of oil prices heralded the end of an era of plentiful and relatively cheap energy. For some countries (Europe, Japan) this era had begun in the late fifties with the commercialization of Middle East oil; for others – i.e. the U. S. A. and Canada – it started as far back as the beginning of the century. First of all in North America, then in Europe and Japan, the energy abundance, both real and expected, encouraged or even generated rapid economic growth and energy intensive development patterns, characterized by the important and rapid spread of road transport and of the car, by the growing consumption of materials with a high energy content, by the urban sprawl, by the generalization of energy intensive habits and behaviours (heating, travels, . . .) and especially, by the development of a whole energy intensive technological infrastructure (badly insulated dwellings, low-efficiency industrial kilns, . . .). This generally resulted in an explosive growth of commercial energy consumption, the world-wide level of which underwent a threefold increase between 1950 and 1973 (previously such an increase had required fifty years).

Paradoxically, in spite of its spread to all levels of industrial societies and although it has become essential to their functioning, energy aroused little interest – especially with respect to consumption – in the last two decades, due to the widespread ill-founded notion that cheap energy sources would be available for a long time – with oil until the turn of the century and nuclear energy thereafter. In addition, the small share of energy expenditure in household budgets or in industrial production costs, with a few exceptions (low income families, basic industries such as steel processing or the cement industry), by no means highlighted the importance of the energy factor. In such a context, the 1973/74 oil crisis came as a real shock, economic indeed, but especially psychological, by revealing how the life styles and more generally the development patterns of industrialized countries were dependent upon energy and how far the countries were vulnerable to restrictions in the amount of available energy or to sudden price increases (inflation, commercial balance, . . .). Today it is undeniable, and the recent 1979/80 "oil shocks" well illustrate this, that the world is facing a long-term crisis. Thus industrial societies should henceforth be prepared for much higher fuel prices than in the past. This brings into focus two great issues concerning the development of the energy market, which underlie this study: how will industrial societies react to this reversal of trend in energy prices, and more especially what will be its consequences upon the evolution of the energy demand? Which energy sources will be able to be mobilized to replace hydrocarbons in order to satisfy this demand, and how soon?

In view of the time-constants of the energy sector, these issues are only meaningful if considered over a long time span. Indeed, the delays between the decision to invest (opening of a coal mine, or construction of a nuclear power station, for instance) and the beginning of production (approximately 7 to 10 years), as well as those necessary to amortize the energy investments (approximately 15 to 20 years) oblige energy firms and governments to consider, within their investment decisions, the development of the energy market over a 20–25 year period – what we refer to as long term. In addition, for similar reasons and in view of the delays necessary for the success of research development programmes, the definition and the implementation of energy policies (supply and demand) can only take place in a long-term context.

One of the paradoxes of the present situation is precisely that one must look at the long-term development of the energy market, at a time when the major uncertainties facing the world (economic crisis, oil supply, . . .) render bold any forecasting attempt. This leads some experts to consider long-term forecasting as a purely academic exercise, or even, in some cases, to refuse the very idea of forecasting. Such an attitude seems to us as dangerous because it ignores the time constraints; it delays the investment decisions or favours random measures, taken in answer to immediate problems, to the detriment of long-term solutions. As emphasized by C. Wilson in the WAES [1] synthesis report, "Time is our most precious resource. It must be used as wisely as energy": the energy decisions upon which rests the future of society, must be made now, but these decisions must rest on a far-reaching perception of the energy market.

Indeed, long-term prospects can no longer simply extend past trends or rely upon the inertia of economic systems, as was currently done for the short and medium term. Too many changes or upheavals in the economic development and structures, in the consumption modes and in the conditions of the energy supply may occur over the next twenty or thirty years, which we can neither ignore nor cast aside. In order to fully comprehend the long-term evolution of the energy market, it is essential to understand how industrial societies use energy and how this consumption changes in time: thus may be identified the major fundamental trends which determine this evolution and upon which one may accurately base the exploration of the distant future. This pre-supposes a deep and detailed analysis of the energy demand, undertaken within an historical and comparative context; this is what we have set out to do in this study.

Such an analysis must be disaggregated and must look at energy at the end-use level (domestic uses such as heating and cooking, industrial uses such as steam production, high-temperature production etc.) for at least two reasons. The evolution dynamics of energy needs are specific to each end-use and thus any attempt to understand the evolution of the energy demand can only be done at the end-use level. In addition, each end-use corresponds to specific energy needs determined by the quantities and the thermodynamic characteristic required: between low temperature thermal energy needs (less than 100 °C, heating, hot water) and average or high temperature, mechanical or electric energy needs, there is little reason to resort to the same energy vector, and the knowledge of the quality of energy required, only possible at the end-use level, is necessary for a satisfactory understanding of future substitutions for hydrocarbons.

The historical and comparative dimension of the analysis is essential to fully identify the dynamic processes and to define possible future developments. An historical analysis limited to a single country is indeed necessary to understand the evolution dynamic of that country's energy consumption but does not allow one to set this development pattern within a more general context; because of this, it only provides partial elements for the evaluation of possible future changes.

The comparative analysis alone, though it does allow one to understand from the differences among countries the links between the technological and economic characteristics of a society and its energy needs, does not help in the understanding of the dynamic processes. The excellent comparative study of Europe, the U. S. A. and Japan, carried out by J. Darmstatter et al. [2] is extremely convincing in its explanation of the different levels of per capita energy consumption, at a given time (1972); it does not, however, explain the dynamics which led to these situations and is of little help in prospective studies. Thus the historical and comparative analyses are obviously complementary for the exhaustive understanding of the phenomena and for any forecasting attempt. A few examples will suffice to illustrate this complementarity.

First of all, the experience acquired in certain energy utilization techniques by some countries may be used as reference by other less advanced countries: for instance, Japan for steel processing, Italy or France for the private car, Denmark and Sweden for the development of heat networks and the insulation of dwellings, and the U. S. A. for solar energy and heat pumps. In addition, the development of public transport networks, both urban and interurban, has been quite different from one country to another, and the experience of certain countries, where transport modes are highly developed, such as Germany or Japan, can prove quite enlightening. Finally, with respect to housing, the differences observed between countries in the spread of household equipment (central heating, electrical household appliances, . . .) allow for a better definition of the range of possible developments.

The countries around which this comparison will centre are OECD countries: for simplification purposes, and in view of the available information, we have restricted this study to countries with a well-established industrialization, providing sufficiently broad field of investigation on the geographic as well as the economic and social levels. Thus we shall frequently include the U. S. A., Sweden, Japan and the main European Community Countries (France, the Federal Republic of Germany, the United Kingdom, Italy, the Netherlands, Belgium and Denmark). In certain cases, other countries, such as Switzerland, Austria or Canada may also be mentioned.

We shall only deal with comparisons which are likely to add to our knowledge of the development dynamics of energy needs and of the links between these needs and the technological, social and economic features of industrial

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