Journal of Power Sources, 37 (1992) 3–12

Trends in the energy market after World War II (WW II)

K. Swart
Hooigracht 32, 2514 BG The Hague (The Netherlands)

Abstract

After WW II, trends developed in the energy markets that continued virtually unbroken till 1972. The main trend was the strong growth of oil as a percentage of total energy consumed. Not only did oil monopolise the rapidly growing transportation market but it also penetrated rapidly into the stationary energy market. In the second half of the sixties, after the discovery of the Groningen Gas field, pipeline natural gas took a sizable share of the domestic and commercial energy market in Western Europe. This market was mainly fed by gas from Groningen, the North Sea and Russia. Another trend was the steady growth of electricity as a percentage of the stationary market partly based on nuclear energy. Coal was the loser. This rather steady development was upset by the first oil crisis in 1972. This crisis was a political crisis which had little to do with the physical availability of crude oil. Between 1972 and the present, periods of reasonable price stability were interrupted by violent swings in the price of oil and gas. Moreover, during this period the environmental movement became a major influence in the energy field. Notwithstanding the generally unstable market, some new trends developed after 1972 and some old ones continued. Will these trends continue long enough to be useful for making a scenario for the future? The forecaster should not assume that the development of energy consumption in the USA, Western Europe and Japan will continue to be of overwhelming importance. Developments in South East Asia and Eastern Europe should be watched very carefully. There are reasons to believe that at a certain stage in economic development, transportation demand shoots up much faster than economic growth, leading to a rapid demand growth for distillate oil. Of importance is also how will the rapidly developing countries generate their increasing demand for electricity and how will they fuel their industry? There can be little doubt that in the rich countries environmental concern will be a major influence in the energy market. But in developing countries environmental concerns take second place to economic growth. Though political influences are impossible to predict, they will continue to upset forecasts based on trends.

Introduction

Trends in energy markets after WW II is a rather ambitious subject for an opening address.

There are many energy markets with different trends and the trends were not continuous from 1945 till 1990. There was an obvious trend break in the early seventies. So I will split the period into pre-1973 and post-1973.

It also seems logical to split the market into the transportation market where oil dominates and the stationary market where coal, oil, natural gas and electricity compete.

There is also an advantage in splitting the energy market into OECD countries and non-OECD countries.

0378-7753/92/$5.00

I do not think I need more categories for this presentation. People are interested in market trends as tools for forecasting. But trends have a habit of changing when you least expect it.

I hope to show you two rather fundamental trends in energy matters that I believe are more or less basic and that will allow some forecasting of market trends. However, there are so many other aspects of the energy market, i.e. there are so many wild cards in play, that no accurate forecasting is possible.

What were the main trends in the period 1945–1973?

In the fifties and sixties energy consumption rose steadily over the period in all regions but rather more strongly in the OECD countries.

It is also clear that oil demand grew faster than energy demand. Oil was in abundant supply. This led to a gradual drop in the real price of oil. Oil was and is traded in US dollars and in the fifties and sixties the oil price did not compensate for the gradual drop in purchasing power of the US dollar.

Competitive forms of energy, mainly coal, had to follow the purchasing power of the money because its production required considerably more manpower than oil per equivalent ton and labour costs were rising faster than coal production efficiency.

The result was that oil pushed coal out of many markets. This trend was stronger in Western Europe than in the USA as coal production in Western Europe was more labour intensive than in the US. Moreover the US had oil import restrictions to protect their own oil industry and therefore also protected coal production. In Western Europe many coal mines were closed resulting in considerable social hardship.

Oil production grew at almost double the rate of energy consumption.

Another important trend was the rapid growth of electricity demand and supply in the stationary energy markets. Generating efficiency also grew steadily, but notwithstanding that, energy input in the electricity generation was growing, to almost double the percentage of energy consumption in general.

It should have been obvious that a higher oil demand than energy demand growth could not go on indefinitely. In the sixties I saw some naive extrapolations that forecasted an annual growth of oil demand of 8% *ad infinitum*, of course showing depletion of the proven oil reserves at a very rapid rate, leading to alarming conclusions. But as total energy demand has grown by four percent over many years, one cannot expect that oil demand will grow at eight percent forever.

Maybe it is time to look at oil demand in a bit more detail. It makes sense to split the oil market into the transportation market and the stationary oil market. The years after WW II saw a very rapid growth of the demand for transportation in the OECD countries.

The motorcar which already had a considerable market penetration in North America before World War II, now conquered the rest of the OECD countries.

I have not found a good study of the psychology of car ownership. There are of course many analyses of numbers and types of motor vehicles, and of their fuel consumption and also for what purposes the trips are made. In the Netherlands a recent analysis showed that almost sixty percent of the kilometers were driven for social, entertainment and holiday purposes. It might also surprise people that many cars only drive about 5000 km per annum or 100 km per week, that is equivalent to one hour driving at highway speed. An owner might spend $15000 for a car and after

10 years with 50 000 km on the clock, the car goes to the scrapheap. To the chagrin of the oil companies in those 10 years the owner has only purchased some 2500 to 4000 liters of motor gasoline which at present at Dutch gasoline prices cost about $2500 to $4000. By far the greatest part of this sum is taxes. It might not make economical sense to own a car, but senseless or not, virtually everybody wants a car. In 1946 there were about 50 million motor vehicles worldwide, of which about 80% were in the USA. Now there are about 550 million cars mostly outside the USA. The growth after WW II was mainly in the OECD countries. It seems that a car is purchased after demands for food, clothing and shelter are satisfied. Car ownership starts to rise rapidly as a country reaches between 2000–5000 dollars of GDP per capita, and reaches about 300–400 cars per 1000 inhabitants when GDP reaches 10 000 dollars per capita. These were 1980 dollars. In Holland the percentage of people between the age of eighteen and eighty having a driving license went up from 15% in 1960 to 70% now. Car ownership in the Netherlands is now 360 per 1000 people and still growing somewhat, but it seems that motor fuel demand is stagnant. Somewhere there must be a saturation point in this market and the OECD countries are not too far from this point.

The transportation market is almost exclusively the domain of oil. Of course there are electric trains, trams and trolley buses but they are a small part of the land transportation system. In air and sea transportation oil has not encountered any competition yet.

In the stationary energy market the position of oil is different. Here oil competes with other forms of energy, mainly coal and where available natural gas.

During the period 1945–1973 crude oil prices dropped compared to coal prices. More and more industries switched from coal to fuel oil and in electricity generation, traditionally the domain of coal, fuel oil gained a marked share as well.

This development had an important influence on the refining industry. It was now profitable for a refiner to distill crude oil into its components naphtha, middle distillates (kerosene and gas oil) and fuel oil. The specification for residual oil required a sulfur content of maximum $2\frac{1}{2}\%$ and this could be met by residues from Venezuela and Middle East crude oils. This led to the building of many so-called skimmer type oil refineries. They were little more than a distilling unit with some equipment to increase the octane number of the naphtha to produce motor gasoline.

Skimmer refineries were simple and relatively cheap. Every country in the world wanted a refinery and an airline. Not that a skimmer refinery gave much employment, and for normal running 100–200 men were sufficient.

Many of these simple refineries were built in the sixties. Few of them made logistical sense but oil companies built them to protect their markets as these so-called local refineries got protection from host governments. Many were built by joint ventures of oil companies as the total market was often too small for more than one small refinery.

In the latter part of the sixties, another competitor appeared on the energy scene, i.e. natural gas. In the USA natural gas had been prominent in the stationary energy market for a long time. But in Europe, natural gas became important with the discovery and development of the huge Groningen gas field in the Netherlands. The gas price was set at a level derived from oil fuels. But since gas burning is cleaner and a gas furnace, especially a small one, is cheaper and easier to operate than an oil or coal furnace, gas made immediate inroads into the stationary energy market, partly at the expense of oil. At about the same time the rapid expansion of Russian natural gas production started. Urengoi, the world's richest gas field, was discovered in 1966.

Wherever pipelines could not be used natural gas was liquefied and transported in special tankers. In this period Japan imported the first cargos of liquid natural gas from Brunei. And there came even more competition for oil in the stationary market as nuclear energy became a real force in the electricity generating market.

When the question is asked as to why from the early seventies the penetration of oil in the stationary market stopped, and to some extent even reversed, the easy answer is that, as a result of the oil shock, oil became too expensive or that the security of the oil supply was considered doubtful.

Partly this was certainly true, leading to a resurgence of coal but there were reasons to assume that oil penetration in the stationary market would have stopped anyway due to competition from other sources of energy.

Environmental considerations pre-1973

Let us now consider one of the most important developments for the energy market, i.e. growing awareness of the environment. As mentioned earlier the specification for heavy fuel oil required a sulfur content of maximum of $2\frac{1}{2}\%$. This could be met, though with some difficulties, by heavy fuel oil produced from the Middle East and Venezuelan crude oils. There were some sources of low sulfur crude oils, e.g. in North America, Indonesia and Africa, but the quantities were small compared to the total market.

As so often with environmental issues the sulfur problem started in the USA. Especially in the Eastern Seaboard of the US, pressure rose for reducing the sulfur content of imported fuel oil. The sulfur specification was gradually reduced first to 2% then to $1\frac{1}{2}\%$ and later even lower. As quantities were small on a world scale, these specifications could be met by reallocating fuel oil from low sulfur crudes to the USA market, of course resulting in leaving more sulfur for the rest of the world.

There was no refining process available to economically remove sulfur from the heaviest component of fuel oil. And there is still no process that can produce a significant amount of 0.3% sulfur heavy fuel oil from 3% sulfur Middle East residual fuel. This is not difficult to understand.

The sulfur in heavy oil is mostly found in molecular carbon ring structures. By taking out the sulfur with a catalytic hydrodesulfurisation process, the only process available, the rings are broken, they become unstable and the heavy oil molecules break into smaller pieces, leaving only a small amount of heavy fuel oil. What one has achieved is conversion of heavy fuel oil to low sulfur distillate type oils which bring a much higher price in the market and such light oil is not sold as fuel for power stations.

Surprisingly, however, most of the crude oil discovered in the sixties and later contains much less sulfur than the Venezuelan and Middle East crude oils.

So, as demand for low sulfur fuel spread to other areas, it was possible to continue to sell fuel oils meeting the new specifications. The heavy components of Middle East crudes went more and more into shipsbunker fuel or were converted to distillates in refineries equipped with conversion equipment.

Electricity generation

One cannot discuss stationary energy trends without mentioning the role of electricity. There is a clear long term trend in electricity generation to processes with higher efficiency. Very roughly, efficiency has risen from 15% at the turn of this century, to over 50% for the state-of-the-art combined cycle power plant today. There is no reason to assume that this trend has stopped; but of course major improvements

are more difficult to achieve as the efficiency gets closer to the thermodynamic limit. It is also clear that over the years electricity took over an increasing share of the stationary energy market. There is also no reason to believe that this long term trend will stop.

As the efficiency of electricity generation increases it will make sense to do more things via the electric route. The first electric lamp fed by the early electricity generators was hardly more efficient than gaslight. That the efficiency of producing light has improved so much is mainly the result of better electric lamps but no doubt also the result of the much higher efficiency of modern electricity generation.

There are quite a number of processes in industry that could be performed via the electrical route instead of the direct heating route using gas fired boilers or furnaces. In many of these processes the electrical route uses half or less of the energy required by the direct route.

The electric route is now hampered by the fact that electricity is delivered to the customer with an efficiency of 35% to 40% only. Would this figure go to 60% then many processes could be redesigned to employ electricity. This might be the cheapest and surest way to reduce CO_2 emissions considerably. An example of such a process is the microwave process. We know this process from the kitchen. Employing a gas oven, one will notice that we are not only heating the food but also the walls of the oven and a considerable amount of hot air escapes from the oven. Moreover, the recipe often prescribes preheating of the oven for a considerable time. All this energy is lost. The microwave oven has much less heat loss. The walls stay cool and little hot air comes from the oven. Moreover, the recipe never requires preheating of the microwave oven.

The same microwave process can find applications in industry for drying and heating.

Another example is the heat pump for home or office heating. Such a heat pump is, simply speaking, the reverse of an airconditioning installation. It pumps up energy taken from the environment to the temperature level of home or office. In general, such a heat pump can deliver $2\frac{1}{2}$ times the electrical energy used, in the form of heat. When electricity is produced and delivered at 36% efficiency the total system efficiency is $2\frac{1}{2}$ times 36%, that is 90%. A modern central heating furnace can perform the same with a much cheaper installation. If we could achieve electricity generation with 60% efficiency then the total system efficiency would be 150%. This would have considerable benefits for the environment, plus a saving of an important natural resource.

It is for such reasons that one can confidently forecast that as the trend of increasing efficiency of electricity generation continues that the trend to do more the electric way, will continue also.

The period 1973 to the present

The oil shock at the end of 1972 was not the only upset in the smooth flow of oil. Before that time we saw twice a closure of the Suez canal. And from 1970 onwards the close observer of the oil scene would have realised that an era was coming to an end.

But it was in 1973 that the man in the street realised that something had gone wrong. Long lines before service stations showed car owners that that problems far from home could have a major influence on their way of life.

The reason for the upheaval in the energy market at the end of 1972 was political. Though people talked of an energy crisis, it was nothing worse than a political crisis as there are so many. This political crisis influenced the availability of crude oil on the world market. There was no shortage of producible oil reserves.

Due to the shortage of available crude oil the price per barrel went up rapidly and with it the price of oil products. Since the natural gas price in Europe was tied to the oil prices, the price of natural gas went up with some time delay. Also the price of coal rose.

After the price peak at the end of 1972, the price of crude oil settled down at around $10/bls.

How did the consuming world react

(1) The oil companies started an active program of exploration for oil in non-OPEC areas. Before 1972 an exploration effort could not afford to pay more than 10 cts. per barrel of oil discovered. After 1972 one could easily afford five times as much if the reserves found were outside the OPEC area. When reserves were discovered they were rapidly brought to production. As a result the percentage of OPEC oil as a percentage of total oil produced diminished.

(2) The oil companies began to build more refinery equipment that converted heavy fuel oil to distillate fuels. Heavy fuel oil prices did not follow completely the rise of crude oil. So conversion of fuel oil to distillates paid off. Skimmer type refineries became uneconomic and a number of them were closed down. Coal partly recovered some of the markets lost to fuel oil but a major part of the stationary energy market was picked up by natural gas and some by nuclear power plants.

(3) Equipment manufacturers developed energy saving products, e.g. car manufacturers got interested in the miles per gallon of their vehicles. Although mutely, they advertised the lower consumption without loss of performance of their products, realising probably that miles per gallon is not a very strong sales argument with their customers. More efficient household equipment came on the market. And much more efficient lamps were developed.

(4) Governments of consuming nations, worried by the balance of payment consequence of the rise of the crude oil price, tried to convince the general public to save energy. I am rather cynical about the long term results of those efforts. Reducing room temperature may work for one winter, insulation has lasting effects.

(5) Industry took up the higher energy price in their calculations for energy saving investments and this led to a gradually reduced energy consumption per unit of production.

The above actions resulted in no noticeable dip in the long term trend of motor vehicle ownership but in a very noticeable trend break in the oil demand. The world economic down-turn was of course a main reason for the trend break in demand for all types of energy.

For years after 1973 the trend of oil demand was flat and after the second oil shock in 1978 the demand for oil in the OECD countries dropped considerably. There were, however, two categories of consumers that continued to demand increasing quantities of oil. Those were first the oil exporting countries which of course, through the higher oil income, became more wealthy and secondly the rapidly developing countries along the Pacific Rim and South East Asia where the economy grows continuously. Those categories of countries quadrupled their oil demand from 1973 to 1990, so compensating for the drop in the OECD countries.

The rapid growth of oil demand in countries that are in transition from an underdeveloped to a developed economy is only partly due to an increase in demand for transportation fuels. A major part of the growth in oil demand is the result of fuel oil demand for industry. Fuel oil distribution requires a rather cheap infrastructure mainly in the form of tank trucks: competitive forms of energy require more expensive infrastructure. Coal firing is not suitable for small factories and light industries. The best way to use coal so far is to install coal fired power stations, but demand is often too low to justify a big coal fired power station. As a consequence we see almost everywhere in the developing world the diesel generator.

In many South East Asian countries there is sufficient natural gas to fuel industry. However, a distribution network for natural gas is capital intensive. In the tropical areas there is no demand for room heating as there is in temperate zones. A fine gas distribution network cannot be justified for cooking only.

One must see these impediments for an energy infrastructure as temporarily. As the economies grow, demand for electricity and gas will be growing and the networks will appear. Then the demand for fuel oil will diminish. One could say a high demand for fuel oil is an indication of an immature energy supply system.

Environmental issues in the seventies and eighties

In the seventies and eighties environmentalists shifted their attention from SO_2 to NO_x. All normal burning of fuels leads to formation of some NO_x. But the attention was mainly focussed on the motorcar engine.

The attack on motorcar emission followed three routes. A catalyst was developed that converted a major part of the NO_x and of the products of incomplete combustion into cleaner exhaust gases. Modification of engine design and control on engine maintenance resulted in a cleaner engine. Reformulation of gasoline produced a lead-free high octane gasoline. These actions resulted in a considerably cleaner motor car. But doubts are voiced whether the internal combustion engine can ever be clean enough to achieve and sustain clean air in a very high density car population in areas where there is often stagnant air.

Environmental issues in the nineties

To forecast environmental issues seems almost impossible, but from the perspective of today worries about global warming is the most likely candidate for the nineties. Good data about global warming are not available but some governments are prepared to take action. When fossil fuels are used there are only two available routes for minimising CO_2 emission.

(i) Improvement of efficiency in all processes that use fossil fuels

(ii) Segregating the CO_2 so that CO_2 can be stored permanently; proposals for such storage are underground storage, e.g. in exhausted natural gas reservoirs, or in deep sea.

Of course an interesting solution would be to use biomass fuels instead of fossil fuels. A route of interest could be the generation of electricity from biogas. Since biogas cannot be produced on a big scale, as transport of biomass over long distances is expensive, the electricity generating system from biomass has to be clean and efficient in small units.

Such biogas electricity, if produced cheaply enough, could be a good alternative for electricity generation where natural gas is not available, or wherever low electricity demand does not justify a long gas pipeline.

After 1991

What may we expect for the future of energy? One has to base such expectations on assumptions. By varying assumptions one gets different scenarios. Technical developments are difficult to forecast for any length of time and they can have a major influence on a market like energy. Therefore it is nearly impossible to make longer term scenarios. If I had to make assumptions for the next twenty years I would choose the following.

(1) When in any country the majority of the population reach a level of wealth that allows them to fulfill the demand for food, closing and shelter, then the demand for transportation will grow rapidly. Part of this demand will be satisfied by private transportation. Expect a rapid growth of car ownership around a level of $3000 GDP/per capita.

(2) In a rapidly developing country fuel oil will initially supply energy to industry. But when in any country demand for energy in industry reaches such a density that an infrastructure for gas and electricity can be installed, the fuel oil demand will diminish. A high fuel oil demand in industry is an indication of an immature energy system.

(3) When for some reason a gradual shortage of oil develops, transportation will gradually monopolise oil as industry has alternatives and transportation has none, at least not for the next twenty years. So-called zero-emission vehicles will not consume a significant amount of fuel in the next twenty years. At this moment half of the oil production goes to transportation and there is no technical reason why crude oil could not be converted into 100% transport fuels.

(4) If, as I assume, electricity generation continues along the trend of efficiency improvement, then electricity demand will once again take up the trend of higher penetration in the energy market.

The rapid improvements in efficiency of electricity end use has for almost two decades resulted in a low growth of electricity demand in OECD countries but the speed of efficiency improvements will slow down to the normal long term trend. So demand for electricity will increase again.

It is of importance for acceptance of new power plants to demonstrate that the plants can be clean and preferably installed in smaller units. A 1000 MW power plant is not considered an asset for a neighborhood.

(5) Watch developments in South East Asia and some countries of Eastern Europe. Together they have a population not much smaller than the present OECD countries. Education levels are high and expectations even higher. Preaching to them to be frugal with energy in order to save the planet will not have much influence and is hardly reasonable. If something has to be done in this respect it has to happen in the OECD countries where there is still considerable scope for saving.

These assumptions lead me to the following expectations:

(1) There will be continued rapid increase in oil demand in the Pacific Rim and South East Asia. If Eastern European countries along the border of the EEC, e.g. Poland, Czechoslovakia and Hungary, achieve the level of wealth that Western Europe had in 1960, then also there car ownership and craving for travel will lead to higher oil demand. What will happen in the rest of Eastern Europe is less clear. But given the fact that the Republic of Russia has huge energy resources it could be possible

that by optimum exploitation of these resources Russia could reach a reasonable level of wealth in twenty years. But there are many examples of countries with beautiful prospects in which the prospect will always remain in the future. OPEC countries will continue to use more of their own oil. In countries with a large population and a small resource base this will lead to less oil being available for export.

(2) Refineries will continue to install more conversion equipment to convert heavy fuel oil to distillate type transport fuels.

(3) Market penetration of natural gas and coal will increase to fill the place of fuel oil. If this does not happen, the demand for fuel oil and so the demand for crude oil will grow uncomfortably rapidly. Utilisation of coal and natural gas requires a rather expensive infrastructure. But not investing in these infrastructures would lead to a too high dependence on oil.

(4) The input of electricity generation, which gradually will become the kingpin of the stationary energy supply, is difficult to forecast since it gives rise to so much political emotion. Whether input will be mainly fossil fuels, or nuclear or so-called sustainable energy sources is now difficult to forecast. But for South East Asia I assume that natural gas is the logical input.

(5) Efficiency of electricity generation from natural gas will have reached 60% before 2010 for the then most efficient plants.

(6) If demonstrations of electricity generation via coal gasification now proceeding are successful this technique will gradually take over from normal coal burning.

(7) Political instabilities will continue to upset the energy markets for at least another twenty years.

Up to here I have tried to limit myself to what I believe has happened and to a smaller extent to what I believe *will* happen, trying to avoid any discussion of what I think *should* happen. I may be excused for ending with a more personal opinion.

Energy is a topic that comes and goes. As and when we have one of those political upsets in the crude oil supply it turns out that there are many experts ready to tell us what to do. It sometimes seems as if the amount of paper printed with articles about energy could, if burned, at least partly solve the so-called energy crises. Next time it is the environmental movement that gets the centre of the stage.

Let us be fair: there is a major problem with the long term resource base for energy and there is a major environmental problem with energy use. These problems have little to do with political upsets or sudden journalistic waves of panic. There can be no doubt that we have to limit the growth of fossil fuel burning sometime. Nothing can grow for ever without giving major problems.

There is still a lot of scope for improved efficiency. I believe that industry and government should sponsor a steady effort of research, development and demonstration of equipment for efficient production and use of energy. The problems we are talking about are long term problems.

It does not make sense to spend a lot of money when there is a panic and then throttle the flow of funds as the markets are calm again. Stop–Go is seldom an efficient way of funding science and technology, but in energy research, which is a long term effort, a steady flow of funds is of major importance.

Almost everywhere governments levy taxes on energy most heavily on motocar fuels. Would it not be sensible to use part of this money to fund R&D aimed at an efficient and clean supply and use of energy.

I believe that subsidies to demonstrate and introduce a new technology are valuable, but I do not believe that subsidies should be part of the structure of an energy economy.

Stimulate the proponents of a new technology. Keep them alive if necessary but don't make them lazy with high subsidies. Governments should set the rules and show the direction society wants to go but then leave it to competition in the market to most economically fullfil the requirements.

If I had to choose only one subject for R&D in sustainable energy I would choose for exploitation of biomass. I would then hope to develop a process that could be applied almost everywhere in the world. Contrary to photovoltaic and wind energy it would not require storage. The process should be able to supply both heat and electricity. It should use human, animal and agricultural waste in an optimum way plus, where necessary, the products of special crops for energy.

You will have noticed that I have not used one word indicating the direct subject of this symposium but I hope that I have made it clear how important it is for the future development of the rich and the poor nations to have available a clean and efficient process for generation of electricity in smaller units. All signs indicate that the electrochemical route is the best contender for such a process. It is therefore in the interest of us all that you are successful in your efforts.