ENERGY SECTOR'S ROLE IN ECONOMIC GROWTH

KIMPTON, Anthony D

CAIRNS, Campbell

KUNI, Doug

ESKOM, South Africa

Introduction

The development of the world economy since the early 1700's has been driven by the supply of energy and there has been a historical trend for societies to develop the systems required to utilize their energy resources In order to support a progressive move through mining, processing, fabrication and assembly activities[1]. The synergistic relationships between these activities and their role in developing an economy is discussed here and by Ayres[2] who describes, for example, how the development of the airplane was dependent on the prior development of the bicycle. As the economy develops, so its focus moves and where the focus of economic development in Europe and America in the 1840's was railroads (physical communications), it is now probably in information communication, entertainment and services. Most economies are, to some extent diversified, but the diversification of the dominant economies of Europe, North America and Japan arises from the migration of these economies through changing value systems as opposed to diversification in nascent economies, which is largely associated with the adoption of the contemporary value systems of more advanced economies.

Implicit in adopting external values is the detrimental role that external economies could play in imposing their requirements on the local economy. Economies have developed in the third world based on products and services that could not be produced or serviced locally. The value of raw materials has declined differentially as the more advanced economies have progressively added value to them and consequently the ability of these economies to upgrade or even maintain the infrastructure they have purchased has deteriorated. There is little hope that the third-world has reached the economic low-point yet, and the indications are that burgeoning population and over-exploitation of natural resources will eventually lead to a total economic breakdown – whatever that implies.

Salvation is popularly perceived to lie in the adoption of so-called appropriate technologies from more advanced economies. Unfortunately the technology and infrastructure that might otherwise empower the economy often conforms to advanced economic values and is essentially inappropriate to the Southern African reality. Technology and infrastructure is generally purchased from external economies, often using external funding, implying neo-colonialist relationships between powerful economies and weaker ones. If nascent economies are developed to achieve sustainable growth, then such relationships could be rewarding - if not, then they are futile or even destructive.

Here we present the view that the development of the underlying sectors of a weak economy is pivotal to achieving sustainable economic growth and that the energy usage within the sectors can be used to guide this development

Energy-based economic development

In order to understand the inter-relationship between energy and economy one must take an historical perspective. This enables one to not only understand the development of the various components of the economy, but the impact that technology, as an enabler, has made. Essentially all countries have followed, or are following, a similar developmental path.

The first economies were essentially primary products based, that is the products were agricultural and raw materials. These industries provided employment for the majority of tie population. To a great extent the current third world is still in this sector. The next economic era came to the fore with the industrial revolution, which expanded the manufacturing base. The manufacture of goods had, of course, always been part of the economy, but the industrial revolution expanded this segment by orders of magnitude, vastly increasing the employment in this sector and making manufacture the dominant part of the economy.

The third era can be called the service economy. This sector of the economy also existed from the very beginning, but with the changing environment and by employing benefits of both scale and technology it became viable to pay for expertise and efficiency in these areas, rather than to do it oneself.

Wind and water power were introduced as the first labor saving devices. Indeed these forms of energy provided the basic motive power for many centuries. The other sources of energy, such as wood, charcoal and other thermal sources (coal was used, but only in small quantities, as were animal and vegetable fats and oils) were used in the relatively small manufacturing sector for smelting, forging, casting and other activities, usually by individuals or small groups.

The service industry consisted mainly of the servant class, who provided service for wages and a relatively small number of service entrepreneurs such as bankers, transporters of goods and entertainers etc. who worked on a commission, piecework or contract basis.

Needless to say the economies were, for the main part, domestically based and most of the trade was relatively local. Some imports and exports occurred, but owing to the relatively long times and high costs involved, they were limited to products that were durable (i.e. not subject to decay or of a fragile nature). Some trade occurred over large distances, but this was of high value per unit volume, such as silks and spices imported by land into Europe from Asia, a very time consuming and expensive commerce. The desire for exotic products was high and It motivated the European voyages of exploration to discover new sea routes to the Indies.

The explorations were successful and led to a major expansion in international trade. Extreme rivalry between the trading nations developed, exacerbated by wars and conflict in Europe.

The growth in international trade led to colonization of territories for a variety of reasons amongst which were the exploitation of natural resources, way stations for ships, havens for refugees, coastal trading stations and as places to dispose of social undesirables.

It must be remembered that the basic energy resources remained essentially the same for many centuries and although there were improvements in efficiency of use of these resources, they remained muscles, wind, water and naturally occurring hydrocarbons. One can now consider the impact that energy and its application via technology had in facilitating economic changes and the impact these charges had on the prevailing socio-demographics.

The agricultural and mining sectors or primary industries form the major initial strength of a countries economy. These were small scale ventures for the most part (although some early mining ventures employed many hundreds of people, mostly slaves) and relied on muscle power from either people or draft animals.

Three key developments occurred in Britain during the second half of th. eighteenth century. These developments were tie use of coal as an energy source, the iron industry and the steam engine. There was a major synergy between these three; the steam engine pumped water from

the coal mines and air into the iron smelters. The iron was used to manufacture the steam engine, which was powered by coal. These developments led directly to a steam powered manufacturing industry. The existing spinning and weaving industries affected were the first effected. The increase In productivity obtained was over 100 within one generation and 1000 in two. It also led to use of cotton (previously an exotic material) as the new devices enabled the Lancashire spinners and weavers to undercut the existing Indian Industry.

Many other industries progressed to steam power, which offered considerable advantages over the traditional forms of energy. The steam engine itself underwent many changes and after about fifty years of development (possibly slowed by patents) became used as a source of motive power, first in the form of railways and later for ships. The introduction of railways not only provided a means of transporting goods quickly and cheaply, but also people. The industrialization of the economy was accompanied by the formation of factories and urbanization. The railways played a major part as an enabling mechanism for this demographic change (for example national holidays, as opposed to local feasts or 'holy days', only became feasible when the entire population could be transported en mass).

Steam powered ships gradually replaced the existing wind-propelled fleets but over a long period, as it was a replacement exercise rather than the introduction of something new, as was the case with the railways: Here stage coaches and canals were rapidly replaced by energy and technology which offered many advantages in time and cost. The steam powered vessels required coaling stations, an infrastructural change which took some time to implement and which introduced new sectors to the economy.

Coals remained the unchallenged primary energy source of choice until the development of the internal combustion engine at the end of the nineteenth century which gave rise to the petrochemical industry. The use of petrochemicals as an energy source offered considerable advantages over coal. They were liquids with a higher calorific value per unit mass. They were easier to transport, easier to store, and smaller quantities were required. The internal combustion engine was much lighter than the steam engine, offering major advantages in cost, power per unit mass, and it was relatively simple to produce and maintain. These benefits gave rise to the motor and aircraft industries. The latter development gave rise to the tourist industry growth that has occurred over last century; encouraged by the jet engine and large passenger aircraft developments which have facilitated low cost travel.

Coal and steam power continue to be used in power stations. The electricity supply industry started in the end of the nineteenth century and is still in its growth period.

Electricity was the last major form of energy to be developed (nuclear energy is another form, but for practical purposes it is considered as a part of the electricity supply industry). It has many advantages over its predecessors, but one major disadvantage - it is difficult to store efficiently at moderate cost Electricity has also led to the introduction of the electronics/information industry. The full impact of this industry has yet to be realized, but its impact is potentially immense.

Occupying a similar developmental period to the electronics industry is the synthetic industry, especially the plastics one. These have a high energy input per unit but are proving viable as less mass is often required and tie forming of components is much easier, resulting in lower overall costs.

If one considers the application and nix of the various energy forms iii the development of the various contemporary economic segments, then certain trends and patterns appear.

The development of a diversified economy

The Introduction of fossil fuel based energy Increased the productivity of existing industries. This often resulted in unemployment initially, but the new energy sources alleviating this problem by introducing new industries and sectors to the economy. There was usually a hiatus before the new Industries were established, and often an adaptation or retraining period for workers was required. Thus although the introduction of tie steam engine had an initial negative impact on many rural trades, it later caused the emergence of many urban manufacturing industries. The

new industries introduced and sometimes replaced existing trades, but often made the service or product available to a much larger segment of the society (the rural trades often persisted, but with much lower manpower).

It can be observed that as new industries or processes we introduced there tends to be a higher return for each unit of energy expended. This actually exacerbates the difference in economic performance and energy consumption between the developed and less- or under-developed countries.

A further broad trend is that as new energy sources and technologies are introduced their implementation requires different attributes. The introduction of powered machinery reduced tie premium on physical strength and increased the premium for manual dexterity. As machinery improved in capability, the dexterity requirement was reduced and the mental premium increased. With the introduction of computers and information technology the need for education and appropriate mental skills increased, and it can be assumed that this trend will continue[1]. Thus part of the infrastructural requirement to implement future technologies will be an appropriate education system.

All countries have an agricultural sector, the more advanced countries produce more per unit area with fewer people than tie less advanced. In mining, for those countries with mining industries, a similar pattern applies. Some countries have not proceeded beyond this stage. Those that have, have a manufacturing sector; again the more advanced the economy the smaller the percentage of the work force employed in this sector.

The services sector is the area in the developed regions that currently employs the majority of the workforce, but this is also being reduced by implementation of computers and information technology. Automatic bank tellers, bar codes, automated inventory systems, and many other devices reduce the need for service-sector employees.

Indeed a new economic sector needs developing in the advanced economies if unemployment is not to become endemic. In the Southern African context there is a need to develop existing sectors to achieve economic growth. The weakness of the diversified economies of Southern Africa lies in the weighting towards sub-economic employment for the majority of the population and the lack of support for more advanced segments from the underlying ones. Accepting the diversified economies and the demographics that are the current reality in Southern Africa, and recognizing the central role that energy plays in an economy, we need to adopt an energy infrastructure development and employment philosophy appropriate to these circumstances. Our goal is to achieve sustainable economic growth, progressing successively through the economic sectors, employing and training the population to support more advanced economic activity.

Economic development and the energy sector

There are many ways of classifying economic activity into sectors, and when we do so we are implicitly attempting to decouple the activities and structures, which together constitute the economic system, with a view to determining the relationships between them. The relationships we observe derive from the non-unique categorization that we have applied to the system and are thus, to some greater or lesser extent, subject to our preconceptions.

Given this qualification then, assuming some such categorization, the causal dependencies between the elements of the economy night be modeled if the integro-differential relationships between its various activities and structures could be established. The usefulness of the model would be determined largely by its ability to generate measures for non-observables within the system and the economy's conformance with predicted behavior. A sufficiently comprehensive model would encompass all the consequences of the various interactions and would change with time[2], but would be impractical on at least two technical counts:

1 Note that in some cases the introduction of new technology has resulted in a net decrease in the competencies required. In general this leads to increased productivity and changing employment patterns.

2 The problem could be defined as that of creating a temporally dynamic, multivariate, spatially distributed model presupposing some well defined domain of interest.

1. Nonlinear relationships within the model are likely lead to sensitivity problems - the predictions of the model would become more and more unreliable in this case.

2. The question of what constitutes a fully comprehensive model needs to be addressed - what can be considered to be exogenous to the model?

From the vantage point of an Energy Utility (whose operations would influence any exogenous variables), it seems unlikely that a sufficiently comprehensive model of the economy could be devised and employed as the basis for long term planning. Accepting that we cannot realistically project far into the future we have instead adopted other rationales for developing energy infrastructure. Energy is not intrinsically committed to any employment; it might be used to ends not envisaged by the planners who developed the energy Infrastructure many years ago, and its usage changes to reflect both prevailing and evolving economic conditions. As a consequence energy infrastructure has historically had three major imperatives directing Its development:

1. Dedicated infrastructure was first developed to supply large demand such as mines, traction, heavy industry and towns. This lead to...

2. Distributed infrastructure developed from existing infrastructure to support agricultural and physical communications activity.

3. Non-committed infrastructure developed from dedicated and distributed infrastructure to encourage and support the economic activity developing as a consequence of the easy availability of energy and the support of existing economic sectors.

Essentially we consider energy to be a resource akin to a river - human enterprise will employ It once Its existence Is determined.

We have advanced the argument that energy plays *the* pivotal role in economic development Examining an economy from the vantage point of the energy supplied to it, this energy fulfills two functions:

1. Maintaining the status quo. This would be energy used to power the telecommunications network, to maintain roads, farm crops, heat houses etc. This energy is known as *maintenance energy*.

2. Changing the status quo. This is the energy used to build vehicles, extend roads, electrify communities, etc. This energy is known as *change energy*.

If energy is not supplied to *change* the status quo, then the economy stagnates. If energy is not used to *maintain* the status quo, then the economy declines[3]. In a growth economy we wish to develop new systems, and in a diversified one we wish to maintain the existing ones. As the economy develops we expect the energy usage to change and the systems underpinning different segments of the diversified economy to require differentially more or less maintenance and change energy. When making decisions as to how best to employ energy, we value different

3 Here we ignore the effects of changing population resources.

systems by different standards with a view to maintaining, refurbishing, replacing, acquiring or discarding them, and the following considerations apply:

1. The functionality of existing system(s) must ideally be duplicated, enhanced or rendered superfluous by any new system(s) unless...

2. Changing values may discount the value of the old system(s) to the point that a reduced functionality is acceptable – perhaps the system(s) might eventually be discarded altogether.

3. The capital cost of an otherwise desirable system(s) might become prohibitively high for a declining economy to support.

While we conventionally value a system with monetary measures, energy measures are just as valid. The energy-cost of supplying a society's needs is insignificant only as long as there is no opportunity cost associated with it. This consideration becomes ever more urgent as energy usage approaches the confluence of several fundamental constraints, amongst which pollution and depleted fossil-fuel reserves loom perhaps the largest. Society has a bequest responsibility to optimize its energy usage within the constraints imposed by the need to achieve sustainable economic growth in the long term.

Economic growth from energy usage

If we monitor the usage of energy in an economy we night expect to discern symbiotic relationships where there is a clear flow of energy between economic sectors. In some cases this energy flow would map to material and produce flow, in other cases it would be perceived as maintenance and change energy supplied to a system common to two or more sectors of the economy.

Energy used in an economy can be categorized Into various forms such as coal, oil, traditional, etc. – these we will term *energy sectors*. If we consider each of these forms of energy and the cost associated with using them, then we find that some forms of energy are preferred in some sectors of the economy[3]. If we consider the energy usage in the various economic sectors then we can develop the concept of *Energy Currencies*.

The ***economic sector energy currency*** $\$_{ec}$ is a measure of the relative energy cost of an economic sector *ec* to an economy.

$$\$_{ec} = \frac{cost\ of\ energy\ \ used\ in\ the\ economic\ sector_{ec}}{gross\ domestic\ product}$$

Alternatively we can define an ***energy sector energy currency*** $\$_{en}$ which gives the relative cost of each energy sector *en* to the total energy economy.

$$\$_{en} = \frac{cost\ of\ energy_{en}}{\sum_{energy\ sectors} cost\ of\ energy_{en}}$$

These measures give us a yardstick to compare economic sectors in terms of their energy usage and opportunity costs. Energy currencies would be specific enough differentiate between different grades of energy sources by the energy costs of extracting, processing and employing them. Thus $\$_{West\ Texas\ Intermediate}$ might differ substantially from $\$_{Tia\ Juana\ Light}$. A refinery might process a mix of such oils to produce its yield, but regardless of the chemical and logistical considerations underlying that mix, the proportional components of the energy currency are still

present in the employment of that currency.

We wish to divorce our energy measure from the time-value-of-money, and so we normalize our expenditure relative to the GDP (i.e. the cost of each energy form used in each economic sector is divided by the GDP). As sectors of the economy develop we expect changing energy usage patterns – maintenance energy will replace change energy as economic sectors mature. Energy flows through productive sectors will be sensitive to the amount of produce, whereas other sectors will not exhibit this sensitivity – they will be infrastructural, offering support to other sectors that are perhaps still developing or unproductive.

The relationship between $\$_{ec}$ and $\$_{en}$ is essentially the relationship between what energy is used for and how it is used.

The elasticity of the measures η_{ec} & η_{en} give the responsiveness of energy cost to energy use.

$$\eta_{ec} = \frac{\Delta(\textit{cost of energy used in economic sector})}{\Delta(\textit{energy used in economic sector})}$$

$$\eta_{en} = \frac{\Delta(\textit{cost of energy used in energy sector})}{\Delta(\textit{energy used in energy sector})}$$

These measures could be used to perform sensitivity analysis and to direct differential development of the economic sectors.

Conclusion

The correct employment of the correct form of energy is the dynamic that has historically developed an economic sector and determined Its long term viability. Communities should be economically viable at every scale (at least in the long term) implying that energy usage too should be optimized at every scale. If energy suppled to an economic sector is not used either directly or indirectly by another sector, then its use should be re-evaluated with a view to improving the mutual dependencies within the economy. These dependencies could be established using the measures we have proposed here.

Where there is sufficient diversity of resources there are multiple opportunities for synergistic relationships between economic sectors. Usually the major barriers to development are not those associated with fundamental resource constraints. They are rather those associated with a lack of political integrity, cooperation and coordination between economic sectors, or more fundamentally, to a lack of trust; not only internally between communities and interest groups but between countries. This, and the very low levels of education and training are usually the main barriers to growth. If these human barriers can be broken down, and If energy is used appropriately within economic sectors, then there is a very real potential for economic growth without dependence on external economies.

Unless a region can afford to utilize modern technologies and implement the necessary infrastructures, it cannot break out of the technology status it currently enjoys. Meanwhile the regions that do implement these technologies Increase their economic well being and consequently are able to implement new developments. Mutualistic relationships between economies offer much for any country, but to avoid the differential demise of the local economy local economic sectors must be developed to support and develop the infrastructure that other economies currently supply.

An economy is a mutualistic system in which individuals co-ordinate their activities and co-

operate in social goals. There has been a clear historical trend throughout the third world to discount mutualistic systems. Infrastructure has fallen into disrepair and communities have become marginally functional as a consequence.

Sustainable communities do not evolve without value systems that encourage interdependence and stabilizes relationships between structures. We have presented the view that these value systems might be energy-based.

References

1. 'A comprehensive Theory of Long Wave Cycles', C S Vollander,Journal of Technological Forecasting and Social Change 32(2), 1987.

2. 'Technological Transformations and Long Waves', R A Ayres, Journal of Technological Forcasting and Social Change 36 & 37, Elsivier Science, 1990.

3. 'Sustainable use of Energy - A normative energy scenario: I 990-2050', J van Ettinger, Energy Policy, February 1994,