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ENERGY PROSPECTS – A CHALLENGE TO INDIAN SCIENCE AND TECHNOLOGY

by

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ABOUT THE SPEAKER

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Dr. Bhaya has held prestigeous positions both in industry and in academic world: Chairman Hindustan Steel 72-77, Director Indian Institute of Management Calcutta 77-81, Chairman Eastern Regional Committee AICTE, Member on the board of IDBI and Industrial Reconstruction Corporation of India, Advisory Board Grindlays Bank, National Income and Wage Policy Committee and the IITs Review Committee, Adviser to the Government of Ghana and Guyana on their public sector administration.

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HITEN BHAYA

It is indeed a great honour to be asked to deliver a lecture dedicated to the great industrialist and visionary Sir Vithal N. Chandavarkar, at this premier Institute of Science & Technology which he guided for many years.

A couple of years back, in this city of Bangalore I had the privilege of delivering the Visvesvaraya Memorial Lecture under the aegis of the Institution of Engineers. I titled my lecture 'ENERGISING INDIA' and outlined the dimensions and problems of meeting our long-range energy needs. The present lecture is addressed more specifically to our scientists and technologists in the fear that more of the same things will never be able to cope with the enormity of the situation and also in the hope that our scientists and technologists will not allow energy to be the paramount constraint to our growth and survival.

2. The approach to energy issues cannot be the same for us as it is for the developed countries. Having attained a level of saturation in per capita consumption and not threatened by a rising rate of population they are more concerned with maintaining the level of energy consumption in the face of depleting primary sources and the rising cost of oil. There is, therefore, renewed interest in more efficient ways of coal combustion, use of natural gas and reduction of specific consumption of energy. Their energy elasticity to GDP growth rate has been brought down to below unity. For us, the resource problem is further aggravated by a rising demand in productive uses as well as consumption needs of the fast growing domestic sector. For us, therefore, more efficient ways of exploring and exploiting our primary resources, of converting them to energy products, of transporting them to the

consumption points, and of specific consumption both in production processes and in direct consumption is a matter of growth and survival. Not all the answers will come from the West. What may be an economic solution for them may still be, and often are, not affordable within our limited resources.

I. Demand for Energy

3. A broad picture of our growth in demand in the next two decades is as follows:–

Our total energy requirements will grow from 135 mtcr in 1984–85 to 516 mtcr by A.D. 2004–05 i.e. 2.75 times – an average annual growth rate of 13.8%.

Sectorwise growth is projected as follows:–

	Increase	Average Annual Growth Rate
Industry	3.82 times	19.4%
Transport	4.00 times	20.0%
Agriculture	3.28 times	16.4%
Household (Total)	1.95 times	9.8%
Commerical	7.00 times	35.6%
Non-commercial	1.34 times	6.6%

Productwise growth is projected as follows:–

Coal from 140 million tonnes to 520 million tonnes
Electricity from 167 Twh to 818 Twh
Oil from 38.8 mmt to 118 mmt.

These projections are based on current trends and technologies and a growth of 5% annual compound. Many feel, and probably rightly, that a 5% growth rate is not enough to attain the minimum quality of life that we wish for the nearly one billion people we may have by then. It is not difficult to see why one assumes the present costs and financial resources against the growth in demand.

II. Exploration & Exploitation of Primary Resources

4. Against this backdrop let us look at the state of our primary sources of energy, first for the conventional and predominant modes of bulk energy, namely, coal, oil gas and radio-active minerals which are non-renewable and then at our renewable resources.

Non-Renewable Resources

Coal

5. We have abundant coal – 158 billion tonnes, of which 139 mts are mineable reserves. But these are unevenly distributed, mainly in 7 States in the South-east quadrant; they are poor in quality with high ash and abrasive matters. As production increases, more coals of inferior grades are being encountered and the calorific value is steadily going down.

6. Coal exploration in the country is carried out in two stages – regional exploration for locating potential blocks within a coal-field and then detailed proving of such potential blocks. Only 53% of the coal-bearing areas has been covered by regional exploration and 350 blocks proved in detail. The results indicate that:–

- 99.5% of the coal reserves are in the Gondwana basin
- 64% of the resources are within 300 metres depth suitable for opencast mining
- Prime coking coal are only 3.5% (5.47 billion tonnes)
- Medium and semi-coking are 14% (22.44 billion tonnes)
- Non-coking coal constitute 82% (130 billion tonnes).
  Of these only 41% are superior grades (A to D) with industrial usage. The bulk of the non-coking coal (68%) is within 300 metres depth.

Detailed proving has so far covered:–

- only 29% of the total resources
- 66% of the coking coals
- 45% of the medium and semi-coking coals and
- only 33% of the non-coking coal.

Thus 10 coalfields extending over 6650 sq. kms are yet to be covered by regional exploration. These include the Godavari and Wardha valleys, mostly beyond 300 metres depth. Similarly, detailed exploration has to be extended to deeper levels in 9 coalfields already under exploitation and 8 virgin fields. At the present pace it takes 7 to 10 years between exploration and mine development.

7. Clearly we need quicker and more reliable cost-effective methods for exploration, mining and upgradation of the quality of coal before it leaves the pithead, for energy use. More effective drilling techniques, newer geophysical methods, electrical, magnetic and gravity surveys, seismic refraction surveys, 3–D and radio-imaging techniques, magneto-telluric and audio frequency surveys need to be pressed into service. Extensive studies in hydrogeological aspects, rock mechanics properties and other geo-mining variables are necessary if we have to achieve the enormous tasks within the bounds of time and resources we can see ahead of us. New mechanised mining methods of both longwall and Board and Pillar techniques have to be introduced fast in replacement of the conventional methods followed so far. Application of electronics and telecommunication in mining is necessary both for safety and for productivity.

8. Preparation of coal before despatch, both for removal of extraneous matter and for reduction of ash content, has been of concern, particularly since the establishment of the large tonnage steel plants in the country. Washeries were set up for coking coals. However, with the passage of time and deterioration of coal qualities in terms of not only ash, but calorific value, volatile matter, micum index and so on, it is clear that better technologies are needed for beneficiation to be cost-effective. More importantly, with the rapid expansion of thermal power generating units the demand for steady quality of coal as a critical input has become equally strident. The years of controversy about beneficiation of coal for the power industry is about to be settled soon, but a great deal of scientific and technical work has to be done before it is to benefit the power industry. The methods of coal sampling and testing seem to be unconscionably long and frustrating. Surely, quicker reliable techniques are possible to be developed if our scientists put their mind to it.

9. There are many other attendant issues in coal mining which also demand better scientific solutions than are available today. These are in the areas of safety in mining operations such as gassy mines or in the context of environmental management – rehabilitation of abandoned underground mines or restoring the ecology of large open-cost mines.

Lignite

10. We have occurrences of lignite of about 3650 million tonnes; most of it is in the Neyveli area, some in Gujarat and in Rajasthan. The Neyveli deposits are being exploited by continuous mining technologies and power and fertilizers are being produced. More intense and rapid mapping, survey drilling and logging are needed in the other areas for full exploitation.

Oil & Gas

11. The situation regarding hydrocarbons, particularly of the liquid variety, is far less comfortable in view of our limited proved recoverable reserves. It is of a greater concern to a developing country like ours where most of our processes and devices are a replication of the industrial development of the West, where steam was replaced by oil as a prime energy source both for motive power as well as for new organic chemicals and materials during a long uninterrupted era of cheap and captive oil supply.

12. Whereas most of the geologically mapped resources in the case of coal can be proved to be mineable and recoverable after detailed drilling, the situation is full of uncertainties in the case of hydrocarbons by the very nature of the trapping and migration of oil and gas underground. Thus, though our prognosticated reserves are stated to be in the region of 9 billion tonnes spread over 1.7 billion sq. kms. in 26 sedimentary basins (1.4 bn sq kms on-shore, 0.32 bn sq. kms off-shore), only about 13 basins (7 on-shore and 6 off-shore) have been taken up for exploration as of immediate interest. Here also, exploration proceeds in two stages. The potential reserves are first established as 'geologically proved in-place' and then further explored to prove as 'recoverable reserve'. Not all of the

recoverable reserve is actually recoverable under normal pressure; it is only about 25% in the case of oil and about 50% in the case of free gas.

13. The results of the exploration so far, show the following:–

- only 25% of the prognosticated reserves have been geologically proved in place (4.65 billion tonnes).
- 62% of the prognosticated reserves are in 3 basins of which only 44% has been proved and is being commerically exploited.
- The distribution of geological reserves is: Bombay-off-shore 59%, Cambay onland 16%, Assam-Arakan 22%, and other on-land 2%. Total on-shore is 39% and off-shore 61%. Share of oil to gas is about 70:30 and two-thirds of the oil lies off-shore.
- 9 other basins have oil/gas indicative of commercial possibilities (Category 2). These constitute 34% of the reserves. Hardly 2% of these has been proved.

14. Thus while prognosticated reserves have little meaning in the medium term one cannot take comfort even in the In-place Geological Reserves. One has really to consider the Recoverable Reserve. The distribution of recoverable reserve is 70% commerically exploitable (Category A&B), and 30% category C where the chances of recovery are 2:3.

The balance of recoverable reserves as on 1.1.1987 was about 577 million tonnes of oil and total hydrocarbon 1100 mt distributed as follows:

Oil 52%, Free Gas 36%, Associated Gas 12%

Over the last decade the addition to inplace reserve through exploratory drilling has been 1680 mt and to recoverable reserve 460 mt. Depletion during this period was 177mt. The current rate of depletion is 30 mt. annual. The consumption of the oil equivalent in the year 2005 is projected to be of the order of 118 mt.

15. A few directions are clear from this hydrocarbon scenario. At the current rate of consumption the present proved reserves will last us less than 20 years and at a rising rate of consumption very much less unless we are able to add to our reserves at a rate faster than the rate of depletion. Given the recovery factor, the addition to the reserves

has to be at least four times higher than the rate of consumption. As it is, a third of our requirements is supplemented by import. This dependence will increase with the years. Nature's bounty as usual is not evenly spread and it is clear that we have to look for oil in more difficult and risky terrains than hitherto. In this context it is critical to find speedier and reliable techniques of exploration and exploitation to derive full advantage of our prognosticated oil reserves.

16. This extends over a wide range of scientific disciplines involved in data acquisition and interpretation:–

In the field of geology, for example – computerised palaeo-ecological modelling based on palaeontological and palynological data, special sedimentological studies like X-ray fluorescence, cathodoluminescence, remote-sensing techniques like pattern-recognition, thermal inertia mapping for direct detection, computerised 3–D basin simulation modelling etc.

In geophysics – vertical seismic profiling, synthetic seismograms, seismic topography, inversion and pattern-recognition, multifold and multichannel seismic data acquisition, use of radio telemetry, Shear-wave data acquisition with horizontal vibrator, improved seismic data processing techniques involving software for structural and stratigraphic modelling, depth migration, beam steering, Expert systems and artificial intelligence.

In geochemistry – isotope gas surveys and geochemical processing, non-destructive source rock logging, use of stereo-chemical and bio-marker isotopes and trace elements, maturation and migration studies.

17. Likewise, in Well Logging, Drilling and Reservoir and Production Engineering, application of new technologies is ever expanding – nuclear and acoustic logging; dielectric logging for detection in fresh waters; carbon and oxygen logging for direct detection; drilling technologies for hard rocks or high pressure sequences; horizontal and automatic drilling, blowout preventer instrumentation, Enhanced Oil Recovery (EOR) techniques like polymer, caustic, miscellar, CO2 and LPG flooding; in situ combustion, downhole steam generator, Early Production Systems – to name a few.

18. In our situation tremendous inputs from science and technology will be demanded from the Oil sector and we cannot always look to the West for these. Even though we have achieved commendable success in rapidly exploiting the Bombay High resources, our foreign outgo in this sector is also high. There is scope and need for indigenisation not merely in hardware by way of rigs and platforms but in software and in expensive chemicals used for drilling, pressure maintenance, viscosity control and other continual operational activities.

Natural Gas

19. It is also evident that natural gas will emerge as a major source of energy for power generation, direct combustion in domestic and industrial sectors, as well as a feedstock for fertilizer and petro-chemical products. An entire vista of knowledge and application is opening before us in the field of gas transportation, gas fractionation and newer fields of utilisation. Production of Ethelyne, Methanol and synthetic fuels is in the horizon. The scientific community have to turn their attention towards these developments even from now.

Atomic Energy Minerals

20. India's nuclear programme, as we all know, is planned in 3 phases with different resource bases:

- The first phase which covers the next two decades is based on natural Uranium (U238) producing electricity and plutonium;
- The next phase is for Fast Breeder Reactors (FBR) using by-products of the first phase reactors – depleted uranium and plutonium; and
- The third phase is FBR using Thorium converting it into U233.

Uranium is, therefore, our primary resource till the turn of the century, followed by Thorium.

21. A 235 MWe reactor needs 61 tonnes of uranium as initial charge and 23 tonnes every year throughout its normal life of 25 years. It is

on this basis that requirements have been worked out for the 10,000 MWe plan for their full life period i.e. for a 40 year time horizon. About 84% of uranium is extracted from Uranium Oxide in the ore-body. Our Uranium ores are low grade ranging from .067% to .025%. The indicated reserves are about 50,000 tonnes with another 23,000 tonnes as inferred reserves against the requirement of 65,000 tonnes. This is spread over 23 belts and seven major deposits.

At present Jaduguda in Bihar is the only production unit. New mines are being planned – 3 projects in the 7th Plan. It takes 2 years preparation and 7 years construction for a mine to come into production. The long-term implication is that about 19 of the 23 belts have to be fully explored and exploited to meet the demand – many of them may be marginal and uneconomic. But we are left with no option as import of uranium is neither desirable nor feasible.

22. Our technology choice has been for Pressurised Heavy water. Therefore, heavy water production is a crucial element. It had run into heavy weather in the past, and the future choice seems to be the ammonia exchange route, near but delinked from fertilizer plants.

23. Our Thorium potential is large, next only to USA and double that of Canada or Brazil. A complex has been set up in Orissa and a Thorium-Uranium plant should be commissioned at the end of the year. An experimental fast breeder unit has also been set up in Kalpakkam.

Therefore, nuclear energy potential has to cross many scientific and technological hurdles until we arrive successfully to the Thorium fast breeder stage, not to speak of the design and indigenous manufacturing capabilities to be developed progressively.

Renewable Resources

24. Our renewable resources are:–

- Fuelwood
- Agricultural waste
- Other biomass
- Animal dung
- Sunlight

- Wind
- Flowing water
- Tidal waves
- Ocean thermal
- Draught animal power and
- Human muscle power.

25. Of these, fuelwood is the most important and critical followed by Agro-wastes and animal dung. All three are basically used in the rural areas and are non-commercial in nature, except for fuelwood which has a considerable market in the urban areas; and all are used to meet subsistence needs of cooking and heating. Draught animal power and human power are mainly employed in agricultural production and rural transport. Conversion to energy products from the rest of the renewable resources is still in various stages of experimentation and development.

26. The renewable sources are widely dispersed over the countryside and have been the main source of meeting the energy needs of rural India using traditional methods unaided by modern science and technology, augmented to some extent by supply of kerosene for lighting and cooking, and diesel and grid electricity for pumping water. 80% of the commercial energy produced in bulk is consumed by 20% of the people living in urban areas. The rest have to fend for themselves as they have for centuries in the past.

27. The task here is therefore to ensure renewability, specially of fuelwood-cum-fodder, and to have feasible technologies of harnessing the other sources. The solutions are, however, not easy by any means. Firstly, there is the dimension of the problem – whenever we are speaking about rural energy issues we have to bear in mind that we are thinking of 600,000 villages and 120 million households of average 5 persons per family, spread over the entire country widely varying in their access to the energy sources, and widely disparate in income distribution, food habits and social mores. Technological solutions to rural energy problems cannot be thought of in purely technical terms but have to be set against the socio-economic parameters in order to be effective. We shall discuss this further in the appropriate place. For the moment, let us turn to the resource position.

Fuelwood

28. Available data is meagre and not too reliable. It has been estimated (Advisory Board on Energy) that even if non-commercial energy in the rural areas were replaced by commerical energy to the extent possible (without considering the constraint of cost and purchasing power) and assuming that chulah efficiency will be raised from 8 to 11% and biogas will be extensively used (not as yet within the reach of owners of less than 4–5 cattle heads), the dependence on fuelwood will remain substantial – of the order of 250–300 million tonnes. Can this be sustained without further depletion of the already denuded forest cover? In other words, can the pace of afforestation match the rate of depletion? A clear positive answer to this question has not emerged from the experience of the various afforestation programmes so far. Therefore, the renewability of this single largest source for energy has not yet been established and the threat of a crisis is very much present with us in the not too distant future. The nature of the dilemma is therefore qualitatively and quantitatively not very different from that of our oil reserves.

29. The Advisory Board on Energy has analysed this issue from the potential land available for plantation and the desired level of yield per hectare and has concluded as follows:

- The demand could be possibly met with planned effort in Rajasthan, Himachal Pradesh, J&K, Madhya Pradesh and, maybe, Maharashtra.
- Punjab, Haryana, Kerala, Andhra Pradesh, Tamil Nadu, Karnataka, Bihar, Orissa, and West Bengal will have problems unless substantial increase in tree cover in natural forest areas and their productivity levels is achieved and pressure from urban areas released through alternative fuels.
- Punjab, Haryana, and Kerala will still have problems and will need supplementing with crop-wastes, briquettes or gasifiers.
- Productivity of Indian forest lands is 'pathetically low' in relation to its potential and needs to be trebled to meet fuel-wood requirements and essential industrial uses.

30. The categories of land considered for fuelwood/fodder plantation are: degraded forest land, culturable waste land, barren land, permanent pasture and grazing land and private farm land. The issue is connected with the larger issues of land-use, reclamation of waste land, supply of inputs and institutional problems apart from science and technology inputs, such as development and demonstration of ecologically compatible fast-growing species, particularly on arid lands, research on aquatic biomass possibilities.

Agricultural Residues

31. These, more than fuelwood (other than lops and tops), are the main fuel for the rural poor. Based on agriculture production targets, the Advisory Board on Energy estimates availability at 480 million tonnes, 100 mt out of this being from foodgrains alone. All of this may not be available for energy use nor distributed evenly. Bagasse for instance, is also a desirable substitute for wood pulp for the paper industry.

Animal Dung

32. On the assumption that 75% of the wet dung will be available for biogas generation and an yield of 40m^3 per tonne of wet dung, approximately 16 million households only can be served. To the extent dry dungcake continues to be used, availability of wet dung for biogas will go down. Land and fodder availability will ultimately determine the number of bovine heads and their yields. Unlike in China the use of human excreta may not gain wide acceptance, though in the North-east pig waste could be used.

Draught Animal Power and Human Muscle Power

33. These are ultimately dependent on balanced food and fodder availability. Little attention has been paid to the upgrading of these potential resources or improving the efficacy of their use by increasing their mechanical efficiency through supplementary devices other than century-old methods. Innovative experiments take place here and there, such as using bullocks for turning simple power generators, but these are rarely improved and taken up for application in significant numbers.

Sun, Wind and Water

34. These are more a problem of technology of conversion to usable forms of energy, thermal or electrical, rather than of availability.

III. Conversion of Primary Sources into Energy Products

35. Let us now turn to some issues in conversion – by conventional and non-conventional methods – of the primary sources – non-renewable and renewable – into energy products. Basically, it is a question of improving the efficiency of conversion of input and energy material to output of usable energy products. Efforts are needed in two directions. One is to attain the efficiency level of established technologies and equipment, all of which we have inducted from developed countries. And the other is to improve upon them by innovation and adaptation. We have mostly been confined to the first stage. But the characteristics of our input materials are different in some critical respects from those on which the imported technologies were based. Therefore, the solution lies in innovation and adaptation through intensive research and experimentation, both scientific and technological.

Electricity

36. Of all the power generation modes, coal-thermal is the predominant one. It is also beset with more problems connected with the input material characteristics than others. Inefficiencies and outages therefore are endemic more in the coal preparation and steam generation stage rather than at the turbine stage. Boilers designed for lower ash cannot cope with the increase in ash; newer designs have to be bigger and less economical; the crushing units cannot cope with increasing impurities; the abrasive matters lead to high corrosion and replacement of ID fans; tubes leak unexpectedly and forced outages deprive us of precious power. The auxiliary consumption of energy at the power stations stands high at over 10%; average coal consumption is creeping up from 0.6 kg per unit to 0.7 kg, and where it is lower, it is compensated by diesel. We seem to have accepted to live with these permanent handicaps without a serious determination to lick them. Are they really beyond the

and comprehension of our scientists and technologists? Granted, many of these problems are aggravated and perpetuated by managerial slack and lack of operational discipline; nevertheless there are some hard-core technical issues to which technical solutions are called for. This is vital, for the simple reason that at the current level of plant availability and utilisation we cannot afford to instal adequate generating capacity to meet power demands, including peak loads, for the kind of projected growth in demand.

37. There is a second reason as to why we cannot afford to ignore these infirmities. As we move to higher and higher units of generation capacity – from below 50 MW to 60 MW, to 110 MW and now to 500 MW – the risks of capacity loss becomes greater. Any unplanned outage in a 500 MW unit can wipe out the economies of scale and also cripple the entire system.

38. We have a long history of research in coal carbonisation, but its impact on the industry has not been marked. It is now, when after the oil shock the developed countries are showing renewed interest in coal combustion, that we have also become alive to the situation. Fluidised bed combustion units – static and entrained, coal gasification, integrated gas combustion cycle operation, waste heat recovery are now coming to the centre of the stage though many problems – such as cleaning the gas of dust in an energy effective manner – are yet to be solved. Again here, developments in the industrialised countries have not had to tackle with high ash low-grade coal which is entirely our unique problem. Do we really expect the outsiders to solve this for us?

Refining

39. Our oil refining capacity is presently about 45 mt and is likely to go up to over 55 mt in the next few years and, maybe, more later. They have been performing well. There is scope for reduction of auxiliary consumption and this is also making progress. However, looking to the future, many new technologies would have to be inducted.

40. The average API gravity of crude fed to the refineries is currently about 34.7. The yield of middle distillates is around 50% and

total distillates can vary from 63 to 87% depending on the nature of the secondary processing in the refinery complex. Taking into consideration the strides being made in catalyst development, the experts feel that there will be a gain in capital costs. The future need, therefore, will be to upgrade heavy oils and to process heavier and heavier crudes with higher levels of impurities, in order to obtain lighter products efficiently. Production of synthetic lubricants is a distinct possibility. This means that the technical requirement at the petroleum refineries is changing from the usual quantitative approach aimed at increasing crude throughput, to a qualitative approach with the goal of upgrading heavy crudes in higher fractions, and move towards zero residue cracking.

Non-Conventional Modes

41. Following the oil shock of the early seventies there was a great concern in the West for reducing dependence on oil and look for renewable sources of energy in the context of global limitations of fossilised fuels. Simultaneously, global concern was also being expressed in environmental protection. It is in this background that Indian interest in non-conventional energy technologies acquired focus. The Fuelwood Policy Committee had already drawn attention to the looming crisis in fuelwood from unchecked deforestation. Since the fall in oil prices, governmental support by way of tax and other incentives has been withdrawn in the West, and firms there are pressing for a market for their still expensive technology and hardware in the developing countries of Asia and Africa.

42. Much is being said and hopes raised about the alternative sources of energy but little is discussed about the present state-of-the-art and the limitations of these modes in fulfilling the potentials of these resources and making any significant contribution towards meeting our burgeoning energy needs in the near future. Some basic parameters in this regard need to be stated and understood.

43. Because of two basic facts, namely, easy accessibility to the primary source which does not need transportation and the unit capacity being small at present, these technologies would be ideally suited for decentralised supply of energy to meet localised needs,

that is the rural areas where grid power is difficult to reach and where hydro-carbon fuels are not feasible to supply in large quantities. But this is where the limitations also come in.

44. Owing to the very large number of rural households any supply mode has to be replicated in sufficient numbers for it to make an impact on the rural energy scene. Secondly, due to the low purchasing power of the bulk of the rural population and the fact that most of them meet their energy needs by collection of lops and tops, agricultural waste and cowdung, at little or no cost, any alternative supply has to be heavily subsidised by the State. Therefore, the higher the capital cost the higher is the subsidy and consequently the lower the extent of coverage. For the same reason it is not possible to sustain any such programme if the devices cannot be produced indigenously in large numbers easily and economically.

Let us examine to what extent the current programmes meet these conditions.

45. BIOGAS PLANTS: Plants of different capacities have been developed and installed, useful for cooking, heating and lighting and even, occasionally, pumping. The slurry is useful as fertilizer. The programme is heavily subsidised; consequently out of a potential of 160 lacs only 9 lacs have been installed so far because of budgetary constraints. These are mostly family units and afforded by relatively better off farmers who own cattle heads. Community biogas plants are less than a 1000 in number because of problems of organisation and participation. Interesting concepts have been developed for composite programmes of cattle being fed in stalls maintained by the community, and supported by a fuelwood-cum-fodder programme combined with community biogas plants and ultimately made self-supporting on the sale of the dairy produce. It is still to be tried out in practice. The long-run problem of inadequacy of availability of wet dung has been already mentioned.

46. SMOKELESS CHULAHS: Apart from smoke, these also help reduce the consumption of fuelwood. The introduction of a portable type by Karnataka has increased the scope considerably. It is almost wholly subsidised as even an investment of 60 or 100 rupees

for a chulah is beyond the reach of millions of people. The coverage, therefore, remains a fraction of the desirable potential.

47. SOLAR THERMAL: Devices for water heating are well established. The current costs are Rs. 50 per litre/watt for large industrial units and Rs. 85 per litre/watt for smaller domestic units. For industrial units the economics are viable but still these continue to be subsidised as the users tend to look upon them as additional standby investments.

48. SOLAR COOKERS: These have gained some urban acceptance with a large subsidy element but their entry into the rural market is negligible in their present design and cost.

While thermal applications have realisable potential, it is a far cry to bulk power generation from these modes.

49. SOLAR PHOTOVOLTAICS: Currently, SPV cells are being made from imported polycrystalline silicon and many applications have been developed for large industrial users but the cost (about Rs. 17 per peak watt) is prohibitive for large-scale application in rural areas. Indigenous production of polycrystalline silicon has commenced and a project for amorphous silicon manufacture is on, but there are many problems still to be solved, particularly stability and effective life under the tropical sun.

50. SOLAR THERMAL POWER: The only known units are 4 or 5 units in California. But ambitious projects are being mooted here for 30 MW units with imported equipment at estimated capital cost of over 3.5 crore rupees per megawatt. Such projects may have an educational value but of little consequence unless costs are drastically reduced and the technology and hardware are fully indigenised. They also require very large land tracts and supply of water. The period of insolation being limited, there are storage issues involved.

51. WIND ENERGY: Apart from direct mechanical use, windmills in tandem are being used for generating electric power (Wind Farms). A few coastal sites have been identified as suitable and 5 demonstration projects have been set up; a few more are

planned. One of them will have a capacity of 0.5 MW. They are all imported. Here also, ambitious programmes are afoot to jump to 10 and 20 megawatts, all with imported equipment. There are problems yet to be studied and solved for transfer to grid power from such units. Some indigenous designs are reported to be under development, but a long way off from being fully indigenous and operational.

Wind pumps are however more promising and 1300 windmills have been set up, but there are still operational problems and a limited availability of indigenous commercial models.

52. MICRO-MINI HYDEL: The potential has been estimated at 5000 MW – 3000 MW with higher heads (micros) and 2000 MW with lower heads (mini). So far only 180 MW are operational and 150 MW are under development. This appears to be a neglected area, though with great utility for meeting local needs. A good measure of design and technical effort including cheaper innovation is necessary.

Other technologies under research and development are:–

- Energy plantation demonstration projects
- Sewage sludge and refuse incineration projects with foreign assistance.
- Ocean thermal energy conversion – a 1 MW plan project at Lakshadwip is planned. Capital cost is high.
- Geo-thermal energy – a cold storage plant and 5 KW unit are being tried at Himachal Pradesh and at the Ladakh valley.
- Tidal wave: a project is under preparation after extended observation in a location in Kutch.

53. One can therefore conclude that intense research and development activities in collaboration with local industries is necessary before any significant contribution can be expected from the non-conventional modes based on renewable sources.

54. BREAKTHROUGH TECHNOLOGIES: Future technologies like Fusion Energy, Hydrogen Energy, and Superconductors which may revolutionise the energy scene, are unlikely to be available to us for large applications in the next two decades, although Indian scientists are working in the latter two areas.

IV. Transportation of Energy Products

55. It is the generation of power and other energy products that usually claims priority of attention, but the technology of conveying power to the consumers or conveying crude to the refineries, natural gas to the users or the storage and transportation of refinery products, all of these have many unsolved problems leading to avoidable losses of energy potential.

56. It is surprising that despite the widely varying degrees of efficiency of the many State Electricity Boards, their Transmission and Distribution losses show a remarkably uniform percentage between 18 to 20% of the energy available at the busbar. Can we afford to live year after year with this kind of wastage in a poor energy-starved country like ours? Although shown as an omnibus figure it can be disaggregated under bulk transmission, secondary transmission network, urban and rural distribution systems, and the theft of power. Apart from commercial and administrative aspects there are technical factors contributing to this kind of intolerable situation.

57. Transmission systems have followed the growth of generation systems over the years. High voltage bulk transmission, for instance, followed the development of large hydro power stations for despatching power to distant load-centres. Gradually extensive networks emerged, followed by steps to integrate these systems Statewise and regionwise. In 1950, there were only 2708 ctkm of 132/110 KV lines. By 1985–86 it had grown to 76,146 ctkm of 132/110 KV, 47,844 ctkm of 230/220 KV and 7826 ctkm of 400 KV. And now with the coming of very large generating stations, the introduction of 765/800 KV lines is being debated. High voltage DC transmission is being tried with foreign technology in the Northern region. And it is a matter of great pride and satisfaction that parallely, right here near Bangalore a composite team of Indian scientists and engineers have developed the same technology and improved upon it radically in the sense that they may be able to find a practical way of transmitting DC power over the existing infrastructure for the AC system.

58. However, the losses are not so much in bulk transmission as in the very large and unwieldy low tension network that has overgrown, not always optimally or scientifically for our rural electrification programme. Rationalisation of these systems, adequate provision of reactive compensation and matching substations need scientific and technical intervention of a significant order. Likewise, reliable and sturdy methods of metering of power flow and consumption are necessary for a check on pilferage of power.

59. We can hardly optimise our power generation and even out peak fluctuations if we cannot ensure free and uninterrupted flow between systems within a region and between regions, nationally. Quite apart from the commercial wrangles there are technical difficulties as well in operating our regional Load Despatch Systems.

60. Though the problems are not as glaring in the matter of transmission of crude and petroleum product lines as in the power sector, there are many areas where science and technology inputs can prevent the level of losses in storage and transportation of these products.

V. Energy Conservation

61. It is abundantly clear that given the limitation of our resources, physical and financial, it can be a losing battle if we try to match the growing demand with enhanced supply capacity and do not take care of the inefficiencies in our supply systems on the one hand, and the enormous wasteful use of energy in all our sectors – industry, agriculture, transport and household – on the other. Energy conservation has many facets, starting from awareness campaigns, simple house-keeping measures and financial incentives and disincentives. But it has also many scientific and technical aspects in which initiative has to be taken.

62. The industry sector consumes now 45% of total coal consumption, 43% of electricity and 14% of oil. In all these areas it is characterised by unwarranted specific consumptions, leakage of steam and oil, old and inefficient boilers, furnaces and the like. Technological intervention is necessary by way of retrofitting of more energy efficient devices, replacements by better devices and development of better values, packing and insulation material.

63. In the agriculture sector, pumps as well as motors can be vastly improved with intelligent modifications.

64. In the transport sector, which is the main consumer of scarce petroleum products, there is urgent need for both short and long-term technological changes. Broadly speaking, short-term changes will be in the direction of evolving more energy efficient engines, reducing body weight, and better transmission and measuring systems. In the long run, development of engines using alternative motive power is needed to move away from petroleum as far as possible, such as use of gas, methanol or electricity.

65. In the household sector, more energy efficient devices for lighting, cooking, space heating or cooling are called for. We are way behind the developments in the rest of the world.

66. TO CONCLUDE: I have consciously strained your patience to drive home the point that there are a thousand areas in our total energy system, from exploration and exploitation to generation, transmission and final use of energy products in all modes and forms that are crying out for scientific and technical intervention, without which we may well run into a crisis situation wherein energy will become our main constraint to growth leading to economic and social stagnation and decay. To my mind, there are two major attitudinal blocks preventing us from tackling the situation in time.

67. Firstly, we react to a situation rather than anticipate it and we tend by and large to look to the developed countries for a cue, forgetting the fact that our primary sources of energy are unique in their quantitative and qualitative aspects. Our distribution and consumption patterns and the dimensions and complexities of our rural scene have no parallels in the developed world. Therefore, it is futile to look elsewhere for possible solutions. This outward orientation has another adverse effect in that we lose our scientific objectivity and tend to become protagonists of one or the other international trend.

68. Secondly, we work in compartments within the shells of our respective institutional affiliations. Energy problems, as I have

tried to focus, are national problems. These are not issues which merely concern Coal India or the ONGC or the State Electricity Boards, the Central Electricity Authority or the Atomic Energy Commission or the Government or the Planning Commission. It affects all of us; it is our common destiny and therefore our common concern. It is the duty and business of everyone, more so of the entire scientific and technical community, to intervene and contribute without waiting to be asked or commissioned to do so.

If this message finds an echo in the minds of some of this community then this memorial lecture would have been a fitting tribute to a dynamic nationalist of the stature of Sir Vithal Chandavarkar.