CHAPTER 3

POWER — FROM MUSCLES TO ATOMS

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"To those who have toiled to make Her great, She has revealed Her treasures one by one."

Introduction

Energy may change through a wide variety of forms, but it cannot be destroyed. When it disappears in one form it reappears in another. Heat, light, electricity, forces of motion and sound waves are different manifestations of the one fundamental entity, energy.

Most of the energy used by man on the surface of the earth originates as solar energy or radiant energy of sunlight. When plant carbohydrates are produced by photosynthesis from carbon dioxide and water, solar energy is stored in organic molecules in a latent form. Animals eat plants and the latent solar energy is transferred to animal carbohydrates and fats. When the animals exert themselves physically, fats and carbohydrates are consumed and latent solar energy is transformed to heat and energy of motion in doing work. Alternatively, plants and animals may be converted into coal and petroleum, which when burned, produce carbon dioxide and water equivalent to the raw materials from which the plants were synthesized, and heat equivalent to solar energy incorporated during photosynthesis.

Quantitative relations exist between the amount of solar energy captured during plant growth, and the food consumed by an animal to do work; the solid or liquid fuel used in driving steam or internal combustion engines to promote motion or generate electricity; and the heat, light or motion produced by using electricity.

Solar energy is also used by man in generating hydro-electric power from river water. Heat energy of sunlight is adsorbed in the endothermal process of evaporating sea water to form clouds which rise to high altitudes whence rain or snow is precipitated on elevated country. This water has potential energy, equivalent to its elevation above sea level, and to the solar energy adsorbed in getting it there, and it can do work flowing downhill to sea level. When rivers are diverted through hydro-electric turbines, the energy is used and converted to electricity.

Another original source of energy is in the disintegration of atoms, which has gone on throughout geological time in the breakdown of radioactive elements, and has now been achieved by man in nuclear science. The total mass of atoms produced by fission or fusion is considerably less than the total mass of the original atoms from which they were produced. The mass lost in the process is converted into energy which appears in the form heat, light, sound and radiation. So the production of nuclear energy represents the conversion of matter into energy, and matter may therefore be regarded as another form of energy.

Early History of Coal Resources

When the First Fleet arrived in Port Jackson in January, 1788, some 1,200 people went ashore to establish the first white settlement in Australia. To live and survive, it was necessary for them to work, and so provide energy for construction of buildings and roads, development of food supplies, control and defence of their community, and a host of associated activities. Steam engines had only just been invented, in Europe 12,000 miles away, and probably few of the first settlers had ever seen machines capable of doing work by converting fuel energy to energy of motion. Their small nucleus of livestock,[1] including seven horses, two bulls and seven cows, together with sheep, goats, pigs and fowls, was of little help as a source of physical energy for 1,200 people. So men and women of the first chapter of Australian history had to use their own muscles to cut timber, hew rock, till soil and transport themselves and their products from one place to another. Working horses and cattle were soon brought from overseas, but even then, and for some time to come, all energy of motion was provided by animal muscles. They used the energy of wind for transport on water by means of sailing craft, but this was of no help on land. Firewood was the first fuel, but used only for production of heat energy at that stage. No doubt tallow, or perhaps plant and animal oils from overseas, were burned in candles or lamps to provide light energy.

The young colony flourished and grew, with a strong impulse to explore and discover national assets. There was an awareness of the advantages which coal may have over firewood, and of its potential future value as a source of energy, through a knowledge of the role it was already playing in Europe.

Within three years, coal was discovered in New South Wales.[2] It was first found in March, 1791, on the coast somewhere north of

[1] Watt, R. D., 1955, "The Romance of the Australian Land Industries", Angus and Robertson, Sydney, N.S.W.; and, King, C. J., 1949, "The First Fifty Years of Agriculture in New South Wales, Dept. of Agric., Sydney, N.S.W.

[2] Branagan, D. F., 1962, "The Borehole Seam", Thesis for degree of Doctor of Philosophy, University of Sydney, Sydney, N.S.W.

Sydney, probably near Newcastle, by a party of escaping convicts led by William and Mary Bryant. Bryant wrote in his diary two days' sail from Sydney that "we found a place where we picked with an axe as good coal as any in England". The party sailed to Timor, where they were recaptured, and news of their discovery did not find its way back to Sydney until some time after later finds of coal had been made. In June, 1796, loose blocks of drift coal were seen at the entrance to the Hunter River.[3] One year later, in August, 1797, George Bass reported the discovery of a coal outcropping above the rock platform at Coalcliff, in the southern or Illawarra coalfield. Only one month after this discovery, Lieutenant Shortland found coal seams outcropping at the mouth of the Hunter River, where Newcastle now stands.

No time was lost in making use of the newly discovered coal resources. By 1798, only ten years after the first settlement, coal was mined by individuals and shipowners at the outcrop of the Dudley seam near the entrance to the Hunter River, and shipped to Sydney. In 1799, private individuals and the East India Company arranged for a shipment of Newcastle coal to Bengal. This was the first export of coal from Australia, and possibly one of the first exports of any kind from this country.

In 1800, Governor Philip King organized coal prospecting operations around Sydney. John Platt, a convict, and the only experienced miner in the country, was set to work with eleven other convicts boring holes and sinking shafts to a depth of about 100 feet. No coal was found, for reasons which became apparent much later when drilling established coal seams at 3,000 feet beneath Sydney. Early in 1801, King decided to move Platt and his "miners" to Newcastle, where they commenced mining the Dudley seam near the present Fort Scratchley. Previously, the Government had placed no restrictions on coal mining by individuals or private companies, but at this stage all mining rights were reserved by the Crown, and a monopoly of State ownership of coal mining followed. Platt's operations were the first regular organized coal mining in New South Wales. It continued for one year in the first instance, during which time 100 tons were exported to the Cape of Good Hope, where it sold for £6 per ton. Mining of different seams by the Government continued intermittently until 1817. Coal was supplied to vessels at about 10/- per ton. In 1814, Governor Macquarie arranged for the export of 154 tons of coal annually to Calcutta, which was to be paid for by the Bengal Government in Bengal rum. By 1820, several mines were operating fairly regularly, and it has been estimated that total production up to 1831 was of the

[3] Hanlon, F. N., 1953, "The Geology of the New South Wales Coalfields", *Coal in Australia. Fifth Empire Min. & Met. Congress,* Vol. VI, Melbourne, Vic.

order of 50,000 tons. State ownership continued until about 1828 when, after much negotiation, the Australian Agricultural Company was granted the right of mining coal in New South Wales. The Company commenced operations in 1830, and by one means and another managed to retain a complete monopoly over coal mining. In 1839, their monopoly was challenged, and other companies commenced independent operations, including some of the first mining in the Illawarra or southern coalfield.

Following the crossing of the Blue Mountains, coal was discovered in 1824 near Katoomba and Lithgow in the western coalfield. It had now been discovered in the three main coalfields of the central eastern coal province of New South Wales, but little if anything was known of the number and varying quality of seams or coal reserves. The need for such knowledge soon became apparent, with rapid progress in settlement, and early industrial development during the first half of the nineteenth century. Coal was needed not only as a fuel for domestic heating and cooking, but as an efficient and economical source of energy for industrial heating, and for steam raising to drive the first stationary steam engines. The coal gas industry had become well established and large quantities of coal were required in Sydney to provide sufficient gas for public street lighting, industrial uses, and domestic heating and lighting. Gas largely replaced candles and oil lamps as a source of light in the cities, and country towns situated in the coalfields commenced installing gas works. By 1850, the first railway and steam locomotives ran 15 miles between Sydney and Parramatta, initiating vast regional development and the building of 10,000 miles of railway by 1900.

Australia shared in the world-wide impetus given to development by the advent of steam railways. The impact in this small, rapidly growing country was relatively greater than in the older and more mature countries. Coal, at that time, was the only source of energy to meet the situation. As rail services extended to the north, west and south from Sydney and the coalfields, demands for coal doubled and redoubled, not only for railway purposes, but for general use as a source of energy in larger country towns situated away from the coalfields.

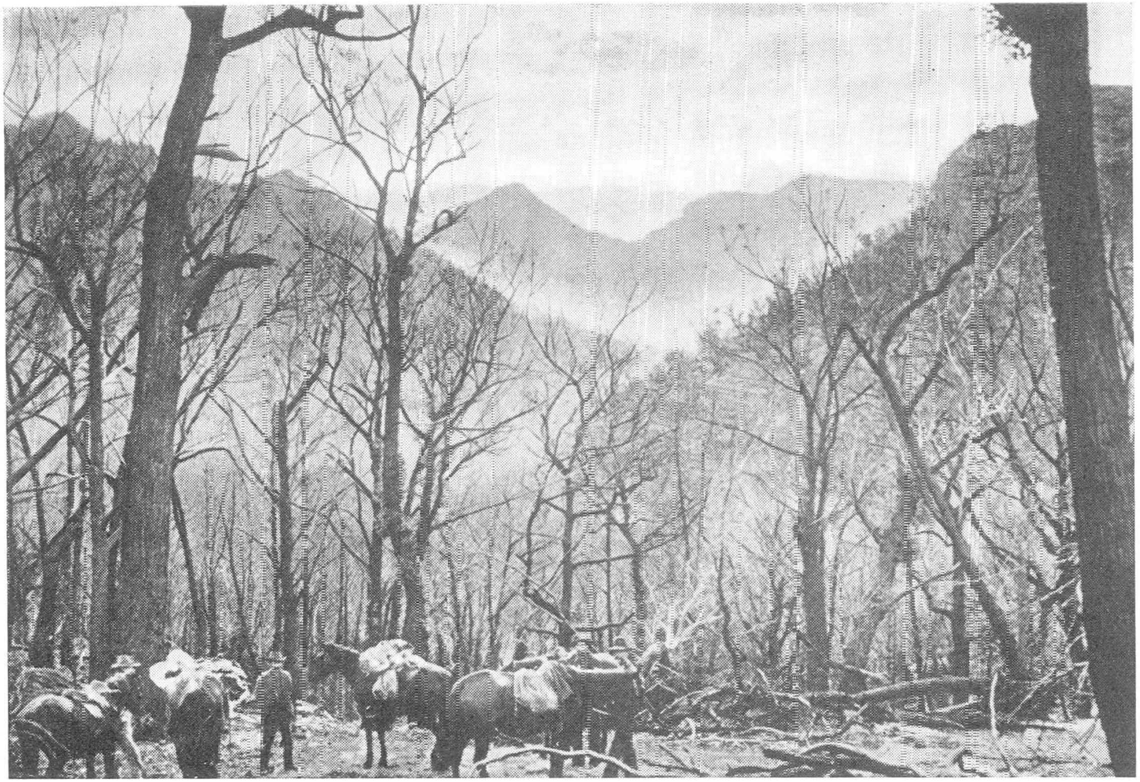
During the last half of the nineteenth century, pioneers of New South Wales geology turned their attention to the structure and stratigraphy of the coalfields, as more and more mining companies commenced production in response to demands for coal. Continuous mining operations were established in the northern coalfield by 1830; in the southern coalfield by 1860; and in the western coalfield by 1870. The first approach to a comprehensive geological investigation of the central eastern coal province was undertaken by the Rev. W. B. Clarke. His early publication, "Remarks on the Sedimentary Formations of New South Wales", laid the first broad foundations of Permian stratigraphy upon which was based much subsequent detail work in the different coalfields. Early field work was fraught with difficulties of wide areas, lack of roads and communications, and a densely timbered

Sir Edgeworth David (sitting) discovered the Greta coal seam at Deep Creek in 1886.

(Photo: N.S.W. Department of Mines)

terrain of almost completely unknown geology. Such work in the coalfields, and other little-known regions, won for Clarke the reputation of being the "Father of Australian Geology".

Much more detail and exact geological work was needed towards the end of the nineteenth century for adequate development of the coal industry and economical production of coal. In 1886, T. W. E. David, later Professor Sir Edgeworth David, accepted the challenge of



A geological field party exploring the Western Coalfield in 1890.
(Photo: N.S.W. Department of Mines)

unravelling the complex and diverse geology of the northern coalfield.[4] He determined and defined the different coal measures occurring within the coalfield, and worked out the stratigraphical arrangement of coal seams in each. He discovered the Greta seam in 1886 at Deep Creek, and the Government reserved 23,700 acres of coal in the vicinity for coal mining. He surveyed the actual outcrop of the unknown Greta coal measures throughout the area in which some of the greatest Australian collieries were eventually established. They included South Greta, East Greta, Heddon Greta, Stanford Merthyr, Pelaw Main, Hebburn and Abermain. David also carried out a survey of the Greta coal reserves in the South Maitland coalfield, which subsequently proved to be the source of the most valuable gas-making coal in New South Wales. In all, he examined and mapped in detail a region extending from Singleton on the north-west, to Catherine Hill Bay on the south-east, including four areas which were to become some of the most important coal districts in the history of Australian coal mining. In 1907, David completed his classical work published as a Memoir of the Geological Survey of New South Wales, "The Geology of the Hunter River Coal Measures, New South Wales".

Geological investigation of the western coalfield was undertaken by J. E. Carne late in the nineteenth century. The area was little known, only partly covered by land surveys, and consisted largely of wild and relatively inaccessible terrain. Geological field work was difficult and hazardous. Carne studied the newly-discovered deposits of torbanite, or so-called kerosene shale, as well as coal seams and coal-measure stratigraphy. The extension of the railway across the Blue Mountain plateau to Lithgow and beyond opened up the western coalfield. Carne worked out the general nature and mode of occurrence of the torbanite deposits and their stratigraphical relations to the coal measures, and published his notable memoir on the "Kerosene Shale Deposits of New South Wales".[5] Some five years later he published results of his work on the coal seams and resources of the western coalfields.[6]

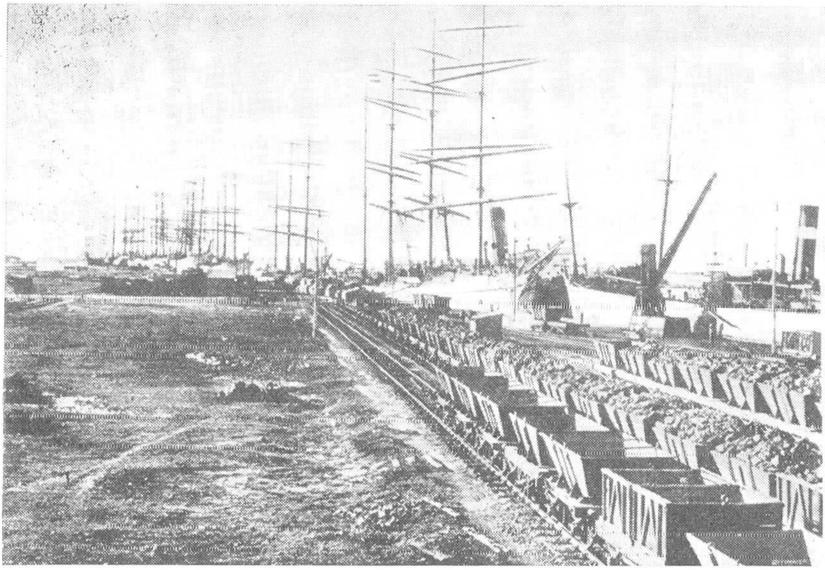
As a result of Carne's geological survey of the western coalfield, and reconnaissance north-east and south-east, it was generally established by this time that outcrops of coal measures were continuous from the northern coalfields, through the western coalfield, to the southern coalfield. This confirmed the basin structure beneath Sydney,

[4] David, T. W. E., 1907, "Geology of the Hunter River Coal Measures, New South Wales", *Mem. Geol. Sur. N.S.W.*, Geol. No. 4.

[5] Carne, E. J., 1903, "The Kerosene Shale Deposits of New South Wales", *Mem. Geol. Sur. N.S.W.*, Geol. No. 3.

[6] ———, 1908, "Geology and Mineral Resources of the Western Coalfield", *Mem. Geol. Sur. N.S.W.*, Geol. No. 6.

and the overall feature of the Sydney basin, with enormous probable coal resources, commenced to emerge. In 1891, a bore at Cremorne, Sydney, struck the top seam of the Permian coal measures at a depth of 2,800 feet, and the probable resources became a reality. Shortly afterwards, coal-mining operations were commenced at Balmain, about three miles from Cremorne, by the Sydney Harbour Colliery Company. A shaft was sunk and the top seam intersected at 2,900 feet. Tunnels were driven in the seam which varied up to 6 ft. 9 in. in thickness. Several attempts at commercial production of coal beneath Sydney were made over a number of years, but they were unsuccessful owing to the depth of the seam and competition of coal produced from surface outcrop in nearby coalfields.



Sailing ships crowded the port of Newcastle in 1900 to load coal for export.
(Photo: N.S.W. Department of Mines)

By 1860 the rural population of New South Wales had grown appreciably. Coal provided energy through steam-raising for transport and mechanical power in industrial areas, and through coal gas for metropolitan heating and lighting. Coal gas also provided stationary motive power in an early form of internal combustion engine which drew gas directly from the mains, and ran on a gas-air mixture by compression-ignition. However, need for a new source of energy had arisen for lighting, heating and motive power throughout pastoral and agricultural regions far beyond the coalfields and industrial areas. The need was met by kerosene, the first of the modern liquid fuels, a light oil or liquid hydrocarbon. It could be burned in lamps for lighting and heating, and used as liquid fuel for some of the first internal combustion engines, known generally as "oil engines". They were regarded as light and portable compared with the heavy steam engines, and although heavy and clumsy compared with the light petrol engines of to-day, they served a very useful purpose in the earliest stages of rural mechanization.

It was found that destructive distillation of the algal coal, torbanite, produced large quantities of a light paraffin-base crude oil, which yielded large volumes of kerosene on fractional distillation. So the New South Wales torbanite, or "kerosene shale" industry was born in 1865 at Hartley Vale, almost concurrently with the inception of a similar industry at Torbane in Scotland. Mining and processing of torbanite flourished at Joadja, Hartley, Newnes and other places in the western coalfields where the principal resources occurred. Coal mining also flourished as the railway pushed further west, opening up vast pastoral areas, and bringing metalliferous ores back to Lithgow, the nearest coalfield, for smelting. By 1900, a small industrial area had been established at Lithgow. It depended on the torbanite industry in surrounding districts, coal mining and metallurgical processing.

Later History of Coal Resources

Soon after 1901, the very rapid evolution of internal combustion engines, from the old "oil engines" to the more modern lightweight petrol models, used for stationary power and in early automobiles, created a world-wide demand for motor spirit or petrol, a more volatile liquid fuel than kerosene. Naturally occurring "well oil" or petroleum, discovered in North America and other countries beyond Australia, was found to be the most economical source of petrol. Kerosene produced from petroleum at the same time as petrol, and at very low cost, was imported into Australia. It quickly subdued the local torbanite kerosene industry, which virtually closed down by 1915. However, coal mining continued to flourish in the western coalfield, and Carne's pioneer work on the geology of the region remained standard reference for many years.

During the history of coal mining in New South Wales, each of the coalfields responded to different demands. The western coalfield enjoyed the boost of the torbanite industry, smelting of western ores and demands for railway locomotive fuel. The northern coalfield, with its Greta seam, captured the market for gas-making coal, and through its numerous seams of good steam-raising coal outcropping near the Hunter estuary, it captured the export market to Sydney, other Australian States and overseas, as well as supplying Newcastle industry with steam-raising coal. The southern coalfield found claim to a different fame which boosted its development. Special coking qualities, unique in New South Wales, enabled its use in production of excellent metallurgical coke for which a demand was rapidly growing by 1900 as metallurgical industries expanded. Coke made in the southern coalfield soon found its way to other New South Wales coalfields and was exported to other States for smelting purposes. At the same time, ores were shipped to Wollongong, where metallurgical industries were established, and another industrial centre was founded.

Early coal mining in the southern coalfield was facilitated by numerous outcrops of coal seams along steep hillsides rising abruptly from narrow coastal plains. There was, perhaps, less need for systematic geological surveying during early development, than in the western and northern coalfields. For this reason, comprehensive investigations were delayed, but as demands for coke increased, problems of underground geology emerged, and the first approach to their solution became the lot of L. E. Harper. He commenced the survey with J. B. Jacquet in 1901, and later assumed full responsibility for the work, which continued for a number of years. Results with important industrial applications were eventually published as a Memoir of the Geological Survey of New South Wales.[7]

The advent of World War I made no great impact on the development of energy resources in New South Wales. Shortly afterwards, however, partly as a result of new technologies developed during the war, domestic and industrial use of electricity commenced to provide new facilities in the use of fuel energy. During the next twenty years, its use revolutionized industry, transport and domestic living. It was generated almost entirely by steam raised in coal-fired boilers. There was no large-scale hydro-electric generation, and no petroleum or natural gas in New South Wales, or Australia, to share in the production of electricity. Practically the only source of electrical energy was coal, and production of this raw material, or "ore of energy" continued to increase, with new demands for more exact geological data in the coalfields and technological data in utilization. Prior to World War II, important contributions to coalfield geology were made by Jones, Lloyd, Morrison and Raggatt, and Dulhunty,[8] but advances in fuel technology and mining engineering were of no great significance. Progress and

[7] Harper, L. F., 1915, "Geology and Mineral Resources of the Southern Coalfield", *Mem. Geol. Sur. N.S.W.*, Geol. No. 7.

[8] Jones, L. J., 1939, "The Coal Resources of the Southern Portion of the Maitland-Greta-Cessnock Coal District", *Geol. Surv. N.S.W.*, Mineral Resources No. 37.

Lloyd, A. C., 1938, "Tomago Coal Measures—Progress Report", *Ann. Rep. Dep. Mines, N.S.W.*, pp. 114-115.

Morrison, M., and Raggatt, H. G., 1928, "Progress Report on Singleton-Muswellbrook Coalfield", *Ann. Rep. Dep. Mines, N.S.W.*, pp. 111-118.

expansion of the industry slowed up considerably during the depression years between 1925 and 1935, but production continued in response to the dependence of Australian national development upon fuel energy.

During World War II, the long-dormant torbanite industry awakened to a short-lived revival, resulting from a shortage of imported motor spirit. The paraffin-base crude oil obtained from torbanite by retorting was found to be an excellent "cracking stock" from which high-grade petrol could be produced in petroleum refining plants. Retorts were built at Glen Davis, in the Capertee valley, on the Newnes torbanite deposit; a small petroleum refining unit was installed; a pipeline was laid to Newnes Junction on the western railway, and motor spirit was produced. Research was carried out on the geology of torbanite deposits and on the technology of liquid fuel production, and large-scale production was planned. However, consumption of liquid fuel for defence and essential purposes increased at such an alarming rate during the war years, it became apparent that installations large enough to supply even minimum requirements would exhaust torbanite resources within a few years. So the industry was allowed to return to its previously dormant state.

Recent Developments in Coal Resources

Following World War II, there came a sudden demand for energy which far exceeded supply, as industry rapidly expanded in application of new techniques, and in availing itself of new opportunities in manufacture and export. A serious power shortage developed, restricting transport and industrial development, and causing the memorable electricity "peak-load blackouts" of 1946 to 1952. The power shortage was due largely to insufficient generating plant, but coal was also in short supply. The Electricity Commission of New South Wales was constituted. It co-ordinated all generating facilities in the State, developed further interconnection of major networks, installed small diesel and thermal power stations at strategic points in the system, and expedited the completion of major thermal generating projects then under construction.

The coal industry adopted emergency measures to boost production. Open-cut coal mining appeared wherever seams could be stripped

Dulhunty, J. A., 1939, "Mesozoic Stratigraphy of the Merriwa-Murrurundi District and South-Eastern Liverpool Plains", *J. Roy. Soc. N.S.W.*, Vol. 73, p. 29.

———, 1941, "Kamilaroi Stratigraphy in the Western Coalfields of New South Wales", *Proc. Linn. Soc. N.S.W.*, Vol. 66, Pts. 3-4, p. 257.

Dulhunty, J. A., 1942, "Stratigraphical Arrangement and Occurrence of Torbanite Deposits in the Upper Kamilaroi Coal Measures of New South Wales", *Proc. Linn. Soc. N.S.W.*, Vol. 67, Pts. 3-4, p. 123.

———, 1945, "Principal Microspore Types in the Permian Coals of New South Wales", *Proc. Linn. Soc. N.S.W.*, Vol. 70, Pts. 3-4, p. 147.

of overburden, using heavy earthmoving equipment available for the first time. Although attempted at many places in all coalfields, successful open-cut mining was limited to relatively few areas, as conditions are largely unsuitable in New South Wales. With one or two exceptions, it served only as an interim measure pending mechanization and development of new mines with high output. By about 1952, production of coal from underground mines, and generation of power at large thermal stations, commenced to catch up with demand. Open-cut mining gradually retracted to favourable sites such as Liddell and Muswellbrook in the northern coalfield, and some of the small emergency power stations, including diesel plants, were taken out of commission.

Coal production had caught up with demand, but before long there arose an urgent need for more economical production and selective use of coal, and improved preparation for marketing, as competition from liquid fuels commenced to emerge. Ships now burned fuel oil, or were powered by diesel engines. The old steam railway engines, which had powered Australian railways through the pioneering days, were being replaced by diesel and diesel-electric locomotives. Fuel oil was being used to fire some stationary steam-raising plants, and petroleum residual products were actually being used with coal in gas-making.

In addition to competition from liquid fuels, plans were completed, and work commenced on the "Snowy Scheme" which would soon produce enormous quantities of electricity to be transmitted throughout the State on the interconnected power system. Furthermore, interstate use of New South Wales coal was waning. Victoria had developed brown coal resources and successfully adapted war-time fuel-engineering developments in Germany to steam-raising and power generation. Brown coal has a calorific value of only one-third that of black coal, contains up to 50% of water as mined, and presents difficult combustion problems when dry. However, scientists and engineers attained the remarkable achievement of producing most of Victoria's electrical and solid fuel requirements by 1960, and so made the State virtually independent of black coal supplies from New South Wales. Also, Queensland had commenced developing vast black coal resources, and was producing its own steam-raising, coking and gas-making coal.

In response, first to coal shortage, then to competition on all sides, a wide variety of research and developmental projects was undertaken in support of the New South Wales coal industry after World War II. Many scientists, engineers and industrial economists working with companies, associations of both producers and consumers, universities and government organizations, contributed to the reorganization and redevelopment of the coal industry. Contributions within the fields of geology, mining engineering and fuel technology, were made by independent groups of investigators working on related problems. They included the Geological Survey of New South Wales, Joint Coal Board, C.S.I.R.O. Division of Coal Research, Electricity Commission of New South Wales, University of Sydney Department of Geology and Geophysics, University of New South Wales School of Engineering and Applied Geology, Australian Coal Association (Research) Ltd. formed by the New South Wales Combined Colliery Proprietors' Association, and laboratories of Australian Gas Light Company, Broken Hill Proprietary Company, and Australian Iron and Steel Ltd., as well as facilities and staff made available by many individual coal producers and consumers.

Never before had the New South Wales coal industry received so much technical attention. Results included almost total mechanization in mining with improved equipment; improved mine maintenance techniques in strata control, and gas, dust, ventilation and spontaneous heating controls; planned mining to meet demands; preparation of coal for marketing and selective utilization; favourable location of power stations in relation to distribution of coal resources and power demands; planned overseas export; more efficient coal using plant; precise and more accurate means of correlating seams and assessing reserves and nature of coal in undeveloped areas; improved laboratory and pilot plant techniques for evaluating utilization potentials of coal; and vastly improved industrial conditions for mine workers.

To-day, the New South Wales coal industry rates with the most modern and progressive in the world.

Electrical Energy

The invention of steam engines and their adaptation to provide mechanical power in industry and transport, may be regarded as man's major achievement in using energy. However, the discovery of electricity, and the practical possibilities of its uses, led to more spectacular industrial progress and remarkable change in everyday life than any other event in the subsequent history of technology.

When electricity is produced in generators driven by coal-fired steam engines, heat energy is first converted to energy of motion, or work done by the engine, and this is then adsorbed by the generator from which it emerges as electrical energy. In using electricity to operate lights, heaters and motors, the energy is converted back again to the forms in which it first appeared as the light and heat of the burning coal, and motion of the steam engine. The use of electrical power generated from coal represents a new and improved way of using energy from a source previously exploited through steam power.

Hydro-electric generation, however, represents the tapping of an energy source previously known, but not used by man in this country to an appreciable extent. Production of electricity in nuclear power stations represents the use of a completely new and previously unexploited source of energy.

The first public appearance of electricity in New South Wales was in 1863, when an arc-lamp, operated by a battery of 100 "wet cells" was erected at the Sydney Observatory as part of the celebrations of the Prince of Wales' marriage. In 1878, arc lighting was used in Sydney to enable completion of the Exhibition Building at night, and in 1882 the Sydney Arcade was lit by arc-lamps. Although these events created much public interest, and provided spectacular lighting compared with relatively dim gas and oil lighting of the day, they must be regarded as important electrical experiments rather than regular practical use of energy as a public utility.

In the meantime, scientific and engineering progress in the use of electricity continued in Europe, and the first electric street lighting in the world was installed in the Avenue de l'Opera, Paris, in 1878.

Australia was quick to avail itself of advantages offered by inventions and developments in other parts of the world, as seems to have been typical of much of her history. In 1882, only four years after the historic street lighting in Paris, electric lights were installed in Redfern railway terminal, and operated by power generated at a small power station in Regent Street. It was the first permanent lighting of a public place in Sydney, and in view of Australia's remoteness from the rest of the civilized world at that time, it surely represents remarkable advancement in technology.

After another six years, in 1888, the first practical, continuously-operated power plant, providing street lighting and electricity for sale to individual consumers, was installed in Tamworth, New South Wales, by the local council. It was the first public utility power supply installed, not only in Australia, but in the Southern Hemisphere. Alderman W. J. Smith knew of the use of electricity in England and America. He went into the matter and persuaded the Tamworth Council to go ahead with the project. The plant was installed by Crompton and Co., of Birmingham, England, for £3,000. It was a large capital undertaking in those days, for a town of only 400 people. It consisted of two 18-kilowatt, 240-volt, direct-current generators, in duplicate (one on standby), driven by steam engines of 15 rated horsepower, with 150 filament lamps of 20 candlepower and 4 arc-lamps. The plant burned firewood as fuel, so the first public utility power station in New South Wales used radiant energy of sunlight stored during the growth of trees only a few years before. To-day, four-fifths of the State's power is generated in power stations which burn coal, using radiant energy of sunlight stored in trees of Permian time, some 250 million years ago.

In 1888, it seemed that the future of electric lighting and power generation in Australia depended to a large extent on the success of the Tamworth 18 kW project. It was successful. The original plant ran profitably for 20 years, when demand for power so exceeded supply that it was replaced by much larger equipment. To-day, plant totalling about 3 million kW is installed in New South Wales, excluding that of the Snowy Scheme.

By 1891, Penrith, Young, Broken Hill, Moss Vale and Redfern all had electric street lighting. Sydney as a whole was slower in adopting a municipal power supply, probably on account of the relatively large scale on which the initial plant would have to be based, and the large capital investment represented in coal-gas plant and associated facilities. However, the Ultimo Power Station was built by the Public Works Department for the Railways Department to supply power for electric tramway services in 1899, and the Pyrmont Power Station for street lighting in the city by 1904. The lighting project was controlled by the Municipal Council of the Sydney Electric Light Department, which had 86 consumers connected to its mains in 1904. Five private companies had established small power stations prior to 1904, and supplied power to the city area. They were brought out by the Municipal Council in 1907.

During the first quarter of the twentieth century, electricity was generated by public authorities at independent power stations, built mainly at large centres of population in central eastern New South Wales. Burrinjuck Dam was completed, and the two power stations, representing the first large-scale hydro-electric project in New South Wales, came into operation in 1928 and 1938, adding 20 MW (megawatt or 1,000 kW) to the State's generating capacity. The First World War saw many amalgamations of generating authorities, and the first interconnection between large power stations. This trend continued, and eventually the first long-distance connection between power stations was made with the construction of the high voltage line from Port Kembla to Burrinjuck before World War II. This link permitted an exchange of thermal and hydro-electric power at different seasons, and demonstrated the advantage of transmitting power long distances between stations situated near primary sources of energy.

During World War II, extensive interconnections were made, and in 1946 the Electricity Authority of New South Wales was established to co-ordinate all existing resources and plan future operations.

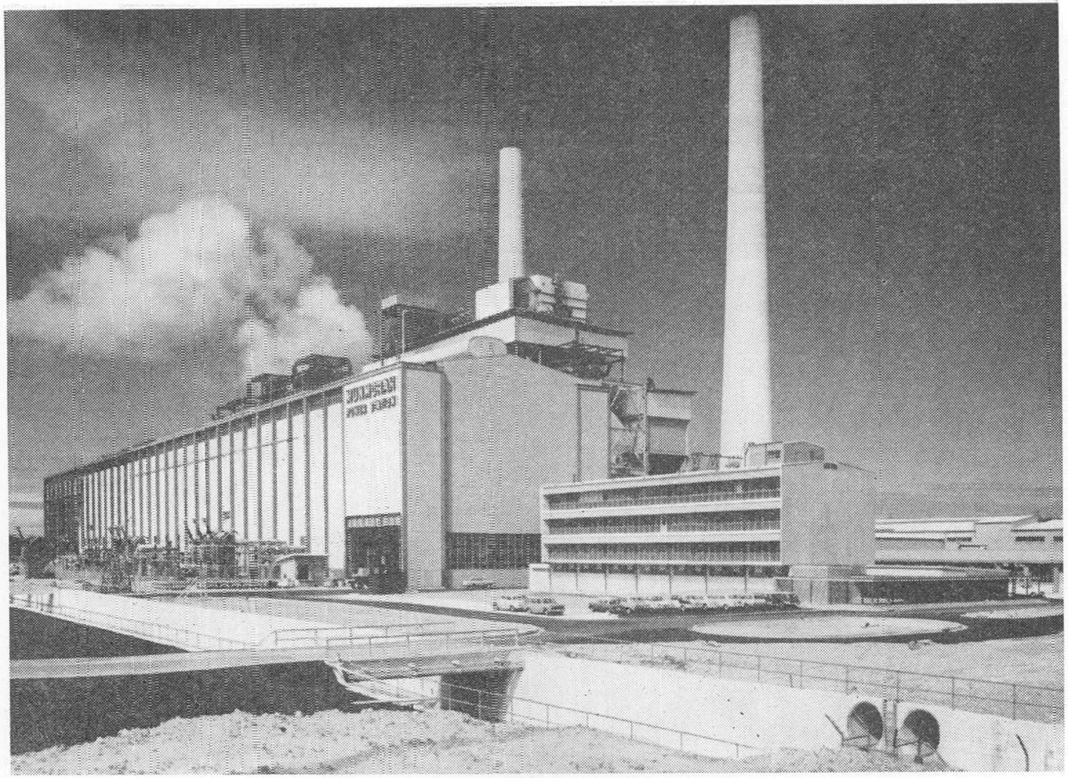
In the immediate post-war years, the development of a hydro-electric water conservation scheme in the Snowy Mountains assumed national importance. A joint Commonwealth-States Committee was set up in 1947 to assess potentials. Its plans were adopted in 1949, and legislation was enacted for the establishment of the Snowy Mountains Hydro-Electric Authority to implement proposals. The Snowy Scheme was complex, involving large tunnelling projects, provision of large regulating dams, deep underground and surface power stations, and a 330-kV transmission system to convey power to load centres in New South Wales and Victoria.[9] This link between the Snowy and the two States makes it possible to use to advantage the diversity of the load requirements of the two main centres, Sydney and Melbourne, a significant factor in the economy of the power supply systems in each of the States. The total planned generating capacity of the scheme is 2,500 MW and the first stage, the Guthega Project, with a capacity of 60 MW, commenced operation in 1955. Since then, three further projects have come into operation, and the total completed capacity at June, 1967, was 1,610 MW.

With the development of the Snowy Scheme, and interconnection between hydro-electric stations in the Snowy Mountains and thermal stations located at vantage points in the coalfields, the present system of generating power at sites of available energy resources, and transmission throughout the State, has gradually evolved. The Electricity Commission of New South Wales was established in 1950 to take over generating and transmission functions from the Electricity Authority of New South Wales and all former State authorities, and to build up the State's power resources into one coordinated system.[10]

Demand for electrical power in New South Wales is now increasing at about 10% per annum. Generating equipment supplying power to the State must at present increase sufficiently each year to provide an additional 380 MW capacity to keep ahead of demand. In addition to increases in capacity as further Snowy Scheme projects come into operation, the Electricity Commission is actively expanding thermal power generation in the coalfields to cope with future demands. Vales Point power station on Lake Macquarie, with a capacity of 875 MW, was completed in 1963. Munmorah power station, under construction at Tuggerah Lakes, will provide an additional 1,400 MW. Liddell power station in the Hunter Valley, on which preliminary work has commenced, will be capable of generating 2,000 MW of electricity, almost as much as the whole Snowy Scheme, by 1974. These three additions to the State's generating plant will together increase capacity

[9] Snowy Mountains Hydro-Electric Authority, 1962, "The Snowy Scheme", Cooma, N.S.W.

[10] Electricity Commission of New South Wales, 1967, "Electricity Supply in New South Wales. A Short History", Sydney, N.S.W.



A modern coal-fired steam power station in 1967. (Munmorah)

(Photo: Electricity Commission of N.S.W.)

by 4,275 MW and increase annual coal production, now 25 million tons, by about 10 million tons in 1974. This rate of expansion in energy production and consumption gives some idea of technological progress in Australia to-day.

The Liddell project will be the newest and largest thermal power station in New South Wales. It will be 100,000 times as large as the first generating plant installed at Tamworth in 1888, and will cost $200 million to build, which is 33,000 times as much as the cost of the Tamworth plant.

Petroleum Resources and Liquid Fuels

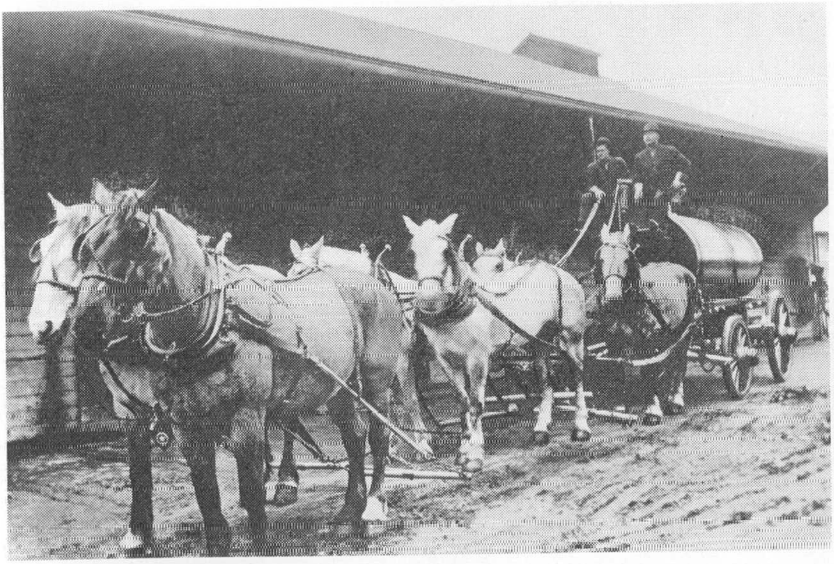
Although bullock wagons and Cobb and Co. coaches using the energy of animal muscles, and later, steam railway locomotives with the energy of coal, were the early pioneers of the opening up of Australia's vast areas during the last century, petroleum products with the energy of liquid fuels played the all-important role in more recent conquest of space and long distances. The wagons and coaches have long since vanished from the scene of energy utilization, and the steam railway locomotives are now following, as diesel power takes over. First automobiles, trucks and farm tractors, then aeroplanes and bulldozers, have played leading parts this century, using petroleum as a source of energy, in progress and development.

Until very recently, the history of liquid fuels in this country has been one of progress in importation, distribution and utilization, rather than development of indigenous resources. Petroleum products have been imported for some 70 years, but Australia's first commercial oilfield was found only six years ago, in 1961. Consumption of liquid fuel climbed steadily over 70 years to the present 4,275 million gallons per annum. The first regular imports of petroleum products commenced in 1895. They were lubricants imported by the Vacuum Oil Company. Kerosene was imported by the Colonial Oil Company, Standard Oil Company and the "Shell" Transport and Trading Company in 1900. Motor spirit was first imported by Colonial Oil Company and Shell Company in 1903.[11] Imports of refined products by British and North American companies continued for many years, as the use of the internal combustion engine, in its various forms, gained impetus and made ever-growing contributions to progress and development. It was not until early in the 1950's that oil companies commenced refining imported petroleum crude oil in Australia. Output of products refined in Australia including liquid fuels and other products was about 870 million gallons in 1955, and 4,500 million gallons in 1966.[12]

[11] Petroleum Information Bureau, 1962, "The Australian Oil Industry", Melbourne, Vic.

[12] ———, 1966*a*, "Oil and Australia", Melbourne, Vic.

The search for petroleum in Australia commenced in a small and sporadic way as early as 1892.[13] Natural gas was first discovered in 1900 during boring operations for artesian water near Roma, in Queensland. In 1906, the streets of Roma were lit with natural gas, representing the first use of indigenous naturally-occurring hydrocarbons in Australia. By 1920, small quantities of low-grade petroleum were found in the Lakes Entrance district of Victoria, initiating prospecting which lasted for twenty years. Some 287,000 gallons of petroleum were produced during this period, but supplies were insufficient for commercial production.



Early bulk delivery of motor spirit in 1915 was a far cry from the road-tankers of to-day.
(Photo: Petroleum Information Bureau)

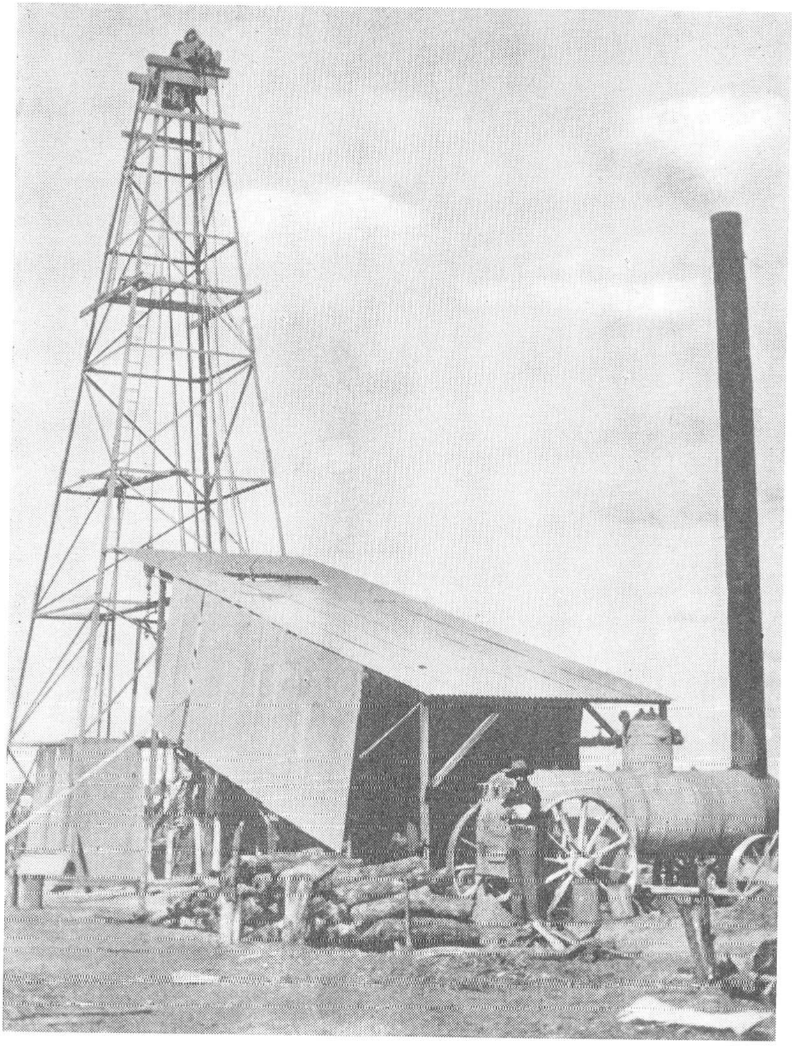
Early petroleum search in Australia was rather unscientific, and boresites were located more by hunch than systematic investigation, which no doubt contributed to lack of success. It was not until about 1950 that properly organized geological and geophysical surveys were carried out prior to drilling.

Positive indications of oil and gas were found early in the history of search in Papua-New Guinea, and some flows were encountered between 1950 and 1965, but commercial fields have not eventuated, in spite of highly scientific and well-organized exploration.

The discovery of oil at Rough Range, Exmouth Gulf, in Western Australia in 1953, although commercially unsuccessful, was one of the

[13] ———, 1966*b*, "Petroleum Search in Australia", Melbourne, Vic.

first definite indications of the probable occurrence of commercial oilfields on the mainland of Australia. It gave great impetus to nation-wide exploration which resulted in the discovery of commercial oil and gas at widely separated places throughout the continent over the



One of Australia's first gas and oil exploration bores at Roma in 1908.
(Photo: Petroleum Information Bureau)

ensuing fifteen years. Further gas flows were found in the Roma district in Queensland up to 1954, and in 1961 a small oil supply was discovered in the Cabawin No. 1 well near Tara in the south-east of the State. Eight months later, on December 3, 1961, Australia's first commercial oilfield was found at Moonie, with a proven initial recoverable reserve of 27·5 million barrels (almost 1,000 million gallons). Commercial gas fields were also found in southern Queensland in 1961, and further oil and gas fields in 1963-1965. Gas and oil were discovered in the Adavale Basin, in western Queensland, in 1965.

Over the period of discoveries in Queensland, gas and oil had been found in the Amadeus Basin, 140 miles south-west of Alice Springs, Central Australia, and gas in the Eromanga Basin, South Australia. Continued exploration in the Exmouth Gulf area resulted in the discovery of Western Australia's first commercial oilfield at Barrow Island in 1965. Later that year, an important natural gas field was found at Gin Gin, 60 miles north of Perth.

Australia's first offshore gas field was discovered in 1965, in the Barracouta well, drilled by floating rig on the Gippsland Shelf, 16 miles off the south-eastern Victorian coast, in Bass Strait. In 1966, continued offshore exploration in Victoria led to the discovery of both oil and gas in the Marlin well, 28 miles from the Barracouta gas field. In the same year, the Moomba gas field was discovered in South Australia, which, in conjunction with the Gidgealpa field, 18 miles away, will warrant a pipeline to Adelaide.

New South Wales has received its fair share of attention in petroleum exploration. It possesses large areas of sedimentary rocks with structures suitable for the occurrence of petroleum, but so far no flows of oil, or gas of any consequence, have been found. New South Wales, Tasmania and Papua-New Guinea are the only Australian States or Territories without any potential gas- or oil-producing wells. At the end of 1966, Queensland had 19 oil wells and 45 gas wells; Western Australia had 17 oil and 4 gas wells; South Australia and the Northern Territory each had 5 gas wells, and Victoria had 2 gas wells.

Oil and gas fields so far proved in Australia are not large on world standards, but they represent a very creditable rate of discovery over the last ten years. Also, their significance is highly important in relation to probable future finds—particularly in view of their widespread pattern of occurrence over the continent. Only limited facilities are as yet available to develop the newly-found resources, and oil production at present represents only 3% of Australia's annual consumption, but this figure is likely to change significantly in the near future.

Nuclear Energy

As yet, Australia has not actually used nuclear energy as a primary source of power, but the country is well prepared for future developments. The history of atomic energy in Australia, so far, is a history of discovery and preliminary production of mineral raw materials, and of technological research towards their conversion to energy.

The occurrence of radioactive minerals in Australia was known long before present-day uses of atomic energy had emerged during World War II. The first discovery was uranium at Carcoar, New South Wales, in 1894, and at Marble Bar in Western Australia in 1904, but little significance was attached to the occurrences at that time. Larger deposits of low-grade ores were found in South Australia at Radium Hill in 1906, and at Mt. Painter in 1910.[14] These deposits were mined spasmodically for radium up to 1934, when operations were abandoned owing to lack of demand and the complex nature of the ores.

No further significant occurrences of radioactive ores were found in Australia prior to 1944, during World War II, when the United Kingdom Government urgently requested a search for uranium ore and its production for defence purposes, the nature of which was unknown to scientists in this country at that time. The Commonwealth and South Australian Governments investigated Mt. Painter and Radium Hill. Some ore was produced, treated and shipped, but the deposits were too low-grade and too small for immediate large-scale development. After the war, the demand for uranium continued. The South Australian Government undertook further work, and by 1950, a process was developed which made possible production at Radium Hill. In 1947, Commonwealth and State Governments jointly undertook an intensive search for radioactive ores in Australia. The Bureau of Mineral Resources, established by the Commonwealth in 1946, was assigned to the search as one of its first major tasks. It undertook field investigations. Samples of metalliferous ores from all over Australia were tested for radioactivity. Methods of prospecting and identification were published, and advice and assistance were given to companies to promote manufacture in Australia of Geiger counters and other electronic prospecting equipment. In 1948, the Commonwealth offered tax-free rewards for the discovery of uranium ore deposits, to encourage individual prospectors and small companies to take up the search. In 1949, a uranium-buying pool was established, and by 1952 profits earned from uranium mining and treatment were exempt from income tax.

The Commonwealth's elaborate efforts to encourage the finding of worthwhile deposits of high-grade uranium ore first bore fruit in the discovery of Rum Jungle in 1949. Mr. J. M. White, a Northern Territory prospector, read the Bureau of Mineral Resources pamphlet on radioactive minerals, illustrated with colour photographs of uranium ore. He had found, some time before, interesting but unfamiliar

[14] Australian Atomic Energy Commission, 1962, "Uranium in Australia", Coogee, N.S.W.

minerals in the Rum Jungle area, which closely resembled those illustrated in the pamphlet, and advised the Bureau of his belief that the outcrop was uranium ore. Extensive investigations of the site by the Bureau established a large high-grade orebody, and Mr. White was awarded the maximum reward of £25,000 for his discovery.

At this stage, the Commonwealth Government realized the need for serious organization of the development of atomic energy in Australia. It first established the Industrial Atomic Energy Policy Committee to investigate industrial applications and recommend a

Discovery of Rum Jungle uranium deposit in 1949. Mr. White holds a specimen of ore while a Bureau of Mineral Resources geologist tests it with a Geiger counter.

(Photo: Australian Atomic Energy Commission)

national programme.[15] The need for a more comprehensive body soon arose, and the first committee was replaced in 1952 by the Atomic Energy Policy Committee, which recommended the present Australian Atomic Energy Committee, established by the Commonwealth Government in 1953. The principal objectives of the Commission have been the discovery and production of indigenous uranium resources, and

[15] Baxter, J. P., 1963, "The First Four Years", *Aust. Atomic Energy Comm.*, Coogee, N.S.W.

development of the use of atomic energy for peaceful purposes in Australia.[16]

The first activities of the Commission were directed towards discovery and production of uranium. It took an active part in organization during later stages of development at Rum Jungle, from 1953 onwards, and encouraged exploration and mining in other areas. It collaborated with the Bureau of Mineral Resources in wide regional exploration; offered technical assistance in production; conducted the discovery reward system, and organized the purchase of uranium ore from independent producers. The advice and assistance of both United States Atomic Energy Commission and the United Kingdom Atomic Energy Authority were sought and obtained.

A widespread uranium boom commenced in 1954. Twenty-two new companies had been established by 1955, to search and mine for uranium. Prospects were traded for large sums, and the boom reached its peak in 1954. All this activity led to the discovery and successful development of Queensland's Mary Kathleen deposit, the largest in Australia, and the South Alligator River field in the Northern Territory. It has now been established that Australia possesses very considerable resources of radioactive mineral, and is well equipped with the raw materials, or "atomic fuels", for nuclear power in the future.

The Atomic Energy Commission has pursued its other objective, the peaceful use of atomic energy in Australia, in many ways during the last ten years. In 1956, it commenced building its Lucas Heights Research Establishment near Sydney, which has now become the major centre of Australian atomic energy research, technical investigation and development. Amongst its principal objectives is the development of a nuclear power reactor for the conversion of atomic energy to electricity in Australia.

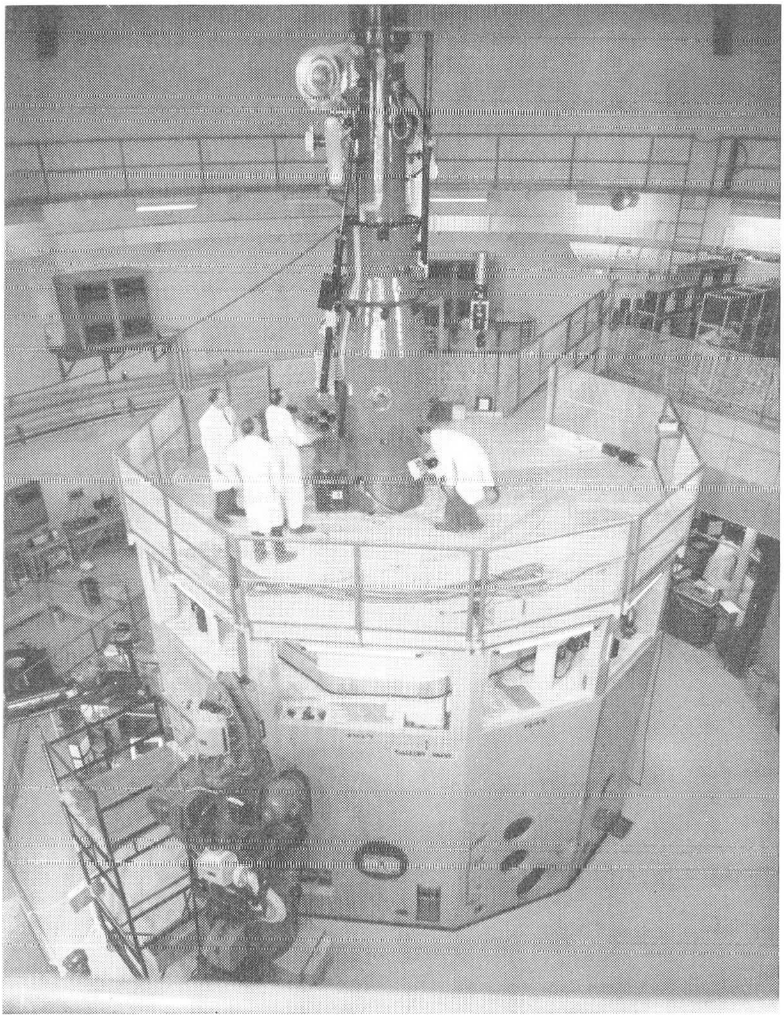
Early in the planning of the Lucas Heights Research Establishment, it was felt that the study of reactor systems would serve the dual purpose of establishing the reactor best suited to local conditions and needs, as well as building up a nucleus of trained personnel experienced in various fields of atomic energy. The Commission first selected two systems for study and investigation.[17] They were the liquid metal-cooled system and a high-temperature gas-cooled system. By 1958, the gas-cooled system appeared to be the more promising, and it was decided that it should be developed. A great deal of work was carried out in engineering investigation and development, materials research and reactor physics, as well as supporting services including

[16] Australian Atomic Energy Commission, 1967, "Atomic Energy", Coogee, N.S.W.

[17] Baxter, 1963, ibid.

The Lucas Heights Research Establishment.

(Photo: Australian Atomic Energy Commission) analytical chemistry, electronics and instrumentation, physics of health and radiation biology. The high-temperature gas-cooled system was believed to be the most suitable for Australian conditions until about June, 1965.[18] However, within twelve months it was found that the



The atomic reactor "HIFAR" at Lucas Heights.
(Photo: Australian Atomic Energy Commission)

system was not wholly satisfactory, and could not compete in capital and operating costs with some reactor systems being developed overseas.[19] Early in 1967, as a result of assessment of all results, the

[18] Australian Atomic Energy Commission, 1965, "Thirteenth Annual Report", Coogee, N.S.W.
[19] Australian Atomic Energy Commission, 1966, "Fourteenth Annual Report", Coogee, N.S.W.

Commission concluded that the system would not be as suitable for generation of power at base load stations, as previously anticipated. As a consequence of its findings, and increasing overseas interest in heavy water moderated reactors for power generation, research is now being directed towards an assessment of technical and economic possibilities of natural uranium-fuelled, heavy water moderated reactors.

Relations between Primary Energy Sources

Coal as a solid fuel, petroleum as liquid and gaseous fuels, hydro-electric and nuclear power, may be regarded as four independent primary sources of energy. Although nuclear power is likely to be very important in the future, it is not yet a general source of energy in Australia, which depends on the other three for all energy requirements. Each primary source possesses its own characteristic limitations and potentials which have determined history of utilization, and upon which will depend future development in Australia.

Coal is limited by geography of occurrence to certain States and certain areas within the States. This restricts the use of coal for steam-raising and power generation to certain areas, beyond which coal must be transported and electricity transmitted. As an energy source, it is also limited by reserves. Production may be varied between wide limits to meet changing demands, but the actual life of reserves depends on rate of production. New South Wales possesses enormous reserves, but they are difficult to assess in terms of years as future consumption, related to changing circumstances, is almost impossible to predict. However, resources will last for many years, and no doubt continue to serve future generations as one of the State's principal sources of energy.

Petroleum liquid and gaseous fuels are more easily and economically transported than solid fuels, but their availability depends on geography of occurrence and life of reserves. Commercial quantities of petroleum and natural gas have been discovered recently in Australia, but national reserves are as yet quite unknown, and at present availability of liquid fuels still depends on international transport and overseas resources.

Hydro-electric power is an efficient and economical source of energy. The life of basic resources in any particular area is unlimited whilst climatic factors remain unchanged, but capacity is strictly limited to volume of water and elevation. When New South Wales develops all practical hydro-electric projects, the limit of capacity will be reached, and production cannot be increased. Therefore, the contribution of hydro-power to the State's future energy consumption will depend on variations in total demands.

The use of nuclear energy as a primary source of power is in development stages in different countries of the world. Rapid progress is being made in technology and economy of operation. Some fifty nuclear power stations are now operating throughout the world, sufficiently economically to compete with conventional fuels wherever they are not readily available at low cost. Another forty stations are under construction. Nuclear power provides a source of energy which is virtually unlimited in both capacity and life of basic resources. It will make possible large-scale generation of power in Australia, at places where coal, oil, gas and mountain rivers are either absent or inadequate, and many such areas offer excellent opportunities for nuclear power generation in this country.

The relative contributions of different primary energy sources to past and present energy requirements in New South Wales are best compared in terms of tons of coal per annum. In the accompanying diagram (Fig. 1), energy derived from hydro-power and petroleum fuels is expressed in equivalent tons of coal, or the tons of coal, with a calorific value of 12,000 B.T.U. per pound, which could produce equivalent amounts of energy. Figures so obtained, and the actual tonnage of New South Wales coal consumed, are then plotted, as three curves, against time from 1890 to 1967. The curves show the relative amounts of energy obtained from each of the three primary sources during this later period of the State's history. Considered together, the upward trends of the three curves provide striking evidence of the almost phenomenal rate of increase in energy utilization over the last fifty years, and particularly since 1950. Considered individually, each curve reflects a different aspect of the State's economic and developmental history.

The coal curve, in Figure 1, illustrates steady progressive increases in demands with industrialization and development of steam power and transport, irrespective of World War I, up to about 1925. Over the next five years, consumption of coal decreased during the "depression years", then increased again at a steady rate until the commencement of World War II in 1939. During the ensuing war years, increase in consumption gradually became less, through limited production capacity, and continued at a low rate until 1945, when sudden post-war demands, met by open-cut production and intense mechanization, provided a sharp increase for the next five years. By 1950, production commenced to catch up with demand, and rate of increase became slightly less. However, from 1955 onwards, the almost explosive rate of progress and national development so boosted energy requirements that coal consumption and production have increased, and are still increasing, at a rate which threatens to become astronomical in the near future.

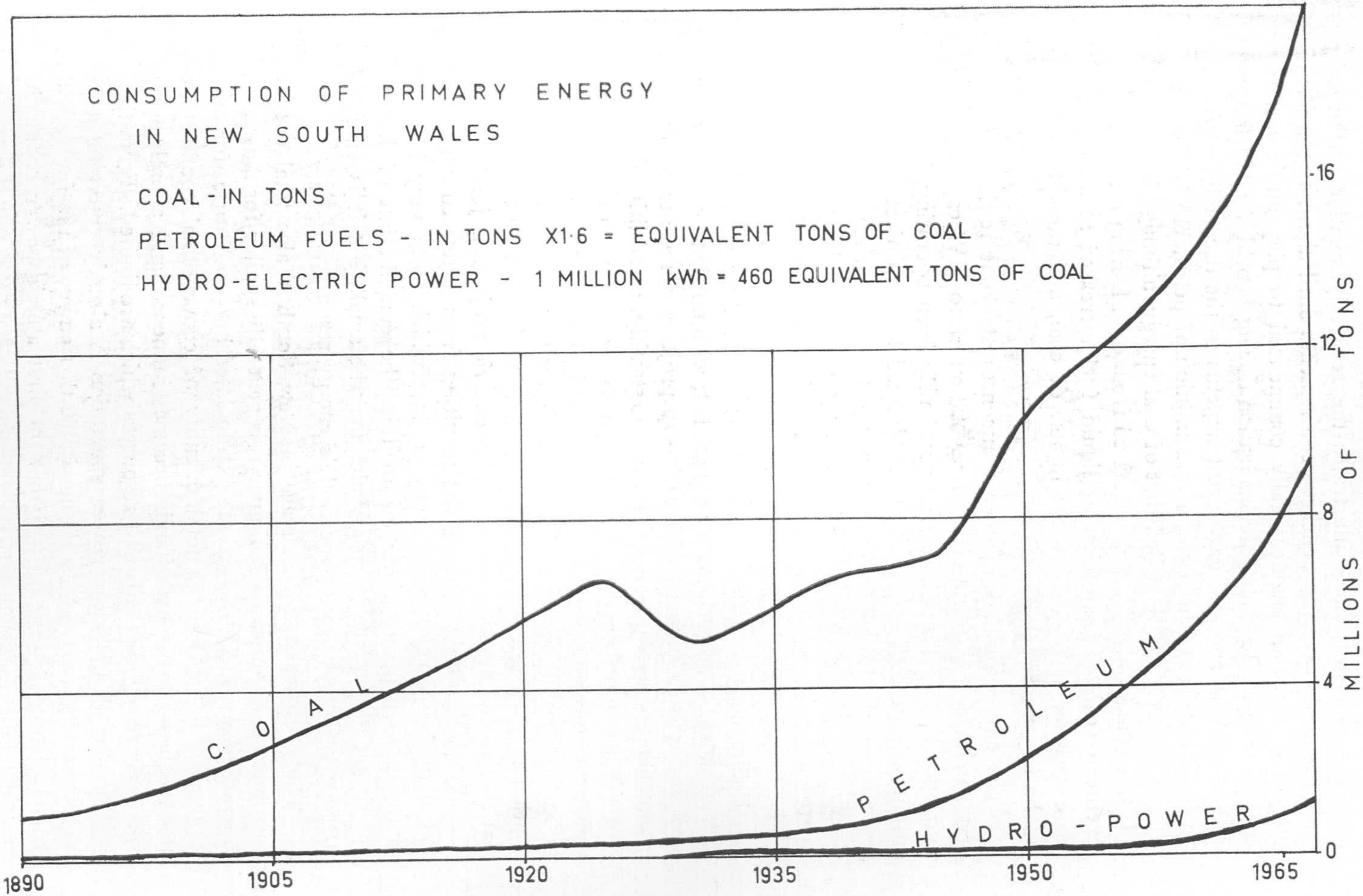

CONSUMPTION OF PRIMARY ENERGY
IN NEW SOUTH WALES
COAL - IN TONS
PETROLEUM FUELS - IN TONS X1·6 = EQUIVALENT TONS OF COAL
HYDRO-ELECTRIC POWER - 1 MILLION kWh = 460 EQUIVALENT TONS OF COAL
COAL
PETROLEUM
HYDRO - POWER
MILLIONS OF TONS
0
4
8
12
16
1890
1905
1920
1935
1950
1965

FIGURE 1.

The petroleum curve illustrates the relatively small contribution made by oil to the State's energy requirements until about 1935, when internal combustion engines really commenced to play an important part in energy utilization. Mechanization during World War II, in the air and on land and sea, gave great impetus to the use of liquid fuels. By 1950, the rate of increase in consumption of petroleum fuel energy in New South Wales equalled that of coal energy, although it provided only one quarter of the energy obtained from coal. During the following seventeen years, consumption of liquid fuel increased at a rate even more spectacular than increases in use of coal, and now it provides one half as much energy.

The curve for hydro-power commences at about 1928, when the first Burrinjuck hydro-electric power station of 10 MW capacity came into operation. Small plants had previously been operating, but their output was of little significance. Additional small projects continued to increase hydro-electric capacity up to 1938 when the second Burrinjuck station of 10 MW capacity commenced operation, and hydro-electric power assumed a very small but significant contribution to the State's energy requirements.

Following 1938, some minor plants added their outputs, but the curve for hydro-power remains almost flat, with no significant increase, until 1955, when the first of the Snowy projects came into operation. From then on the curve rises slowly but steadily, as additional Snowy projects are added, to the present capacity equivalent to a little over 1,000,000 tons of coal per year. It will rise by perhaps another 1,000,000 tons in the near future. This may appear to be small, in relation to the State's total requirements, but it must be remembered that the cost of development of hydro-electric projects is justified, and virtually paid for, by the benefits resulting from water conservation, and that electricity is really a by-product which costs very little, if anything, to generate. In view of this, the contribution of hydro-electric power in New South Wales may be small, but it is valuable in the overall economy of the State's energy resources.

The present rate of increase in New South Wales total energy consumption, as indicated in Figure 1, is generally similar for Australia, and for the world as a whole. If extrapolated into the future, for only a few decades ahead, the total quantity of conventional combustible fuels required to meet demands becomes immense, and apprehension must arise regarding the life of resources which are limited. From this, and the fact that nuclear power generation is already emerging as a practical facility, it would seem inevitable that power of the future will depend on nuclear energy, and that the first atomic power station in Australia must soon appear.