Careful consideration of the trend of recent developments in the great industrial countries of the world shows that further progress in national efficiency requires a closer interweaving of the industrial fabric and a better use of geographical factors. Recognition of the importance of these principles has led to their incorporation in national policies, inducing great changes in industrial structure and national lay-out.

The co-ordination of enterprise was instituted to avoid overproduction in one field attended by inadequate development in another, to prevent waste of man-power and capital spent on duplication of services in excess of requirements, to conserve mineral resources by their more economical use, and to treat raw materials by alternative methods in such amounts that all the by-products could be readily absorbed by collateral industries. In general, the chief objective was to reduce national waste, and to take fewer false steps that would have to be retrieved and paid for.

Of first importance is the selection of places most suitable for the establishment of industries. Apart from the paramount question of national defence, the chief determining factor is the purpose for which each manufacture is to be undertaken—whether it is to be for local consumption only, or if not, what proportion is to be for export. Then the final location is one of endeavouring to obviate unnecessary transport by placing the factories as near as possible to the sources of their raw materials—for example, steel works should be near the mines or seaports. The problem is further complicated by the various raw materials required for an industry lying in various places remote from each other; here it is common to transport the less bulky to the source of the more voluminous—the ore to the coal, for instance; although a proportion of the lighter material may be back-loaded to the source of the heavier, and factories may be established at both places. An example of this is the interchange of coal and iron ore between the States of Ohio and Minnesota, via the Great Lakes. Factories for the export of heavy goods are located near the seaports, main canals, or else on the international trunk lines of communication. All these innovations require the migration of the industrial community and the building of new cities, complete with all their services. The agricultural population is left undisturbed, and
large numbers of smaller specialised industries retain their quota of highly skilled artisans, who remain in their original habitations; but there is a gradual transfer of the great mass of the industrial population to new centres, which for the present day are more convenient than mediaeval cities, founded in other days for other purposes.

After these questions have been settled, there follow the important problems of selecting the optimum size and constitution of each organisation consistent with the achievement of maximum economy—problems involving the intricacies of engineering, economics, and sociology. Then come the inter-relation of heat, power, and chemical by-products, and the delimitation of their respective economic spheres; so also the prevention of waste by co-operation and interchange among neighbouring factories. These matters were reviewed by the writer in two preceding addresses.*

All these problems have been receiving more intensive study in Germany than perhaps in any other country. Subsidised committees were set up to study markets, actual and potential, local and foreign, and how to strengthen rural life in order to improve the local rural consumption. Standardisation, fuel economy, co-operation among industries and among different forms of transport, all had their boards, many of whose decisions were regarded almost as mandatory. Following the guidance of these representative advisory bodies, definite policies were adopted and are being pursued, some of the fruits of which are already apparent in the vast reorganisation of German industries, leading to wholesale scrapping of obsolete plant and transfer of activities to localities best suited for them.

When instituting such policies, many difficult financial, political, and social problems are encountered. These lie outside the scope of engineering; but a knowledge of how these principles are being applied in older countries would be profitable to the engineer and the public of Australia where precise information is not so readily obtainable as it is in Great Britain, Europe, and America. There has been frequent reference to the subject in general terms in the press and current literature, but a brief technical survey with concrete illustration of co-operation among very large branches of industry should prove of greater value.

*"The Higher Emerging Relations of Power Heat and Chemistry" and "Industrial Reciprocity in the Supply of Power and Heat," Proceedings Victorian Institute of Engineers for March, 1930 and 1931 respectively.
Prior to the War, with the exception of Upper Silesia, practically the whole of the coal, iron and steel industries of Germany were concentrated in Lorraine, and in the basins of the Ruhr and the Saar. Consequent upon the terms of the Peace Treaties, the Saar and Lorraine were removed from her charge, Luxembourg was detached, and Upper Silesia lost by partition, so that Germany found her coal productivity reduced to 75 per cent. of the pre-war value. In addition her chief source of iron ore, the "minette" deposits of Lorraine were no longer available, and her producing power of pig iron was reduced by 41 per cent., steel ingots by 51 per cent., and rolling mill products by 39 per cent. These reductions were partly due to the destruction of heavy engineering plants classed as armament works, by the technical section of the army of occupation, and also because some plants passed away from her with the lost territory. On the other hand, it is said that the material-consuming industries, such as engineering, machinery, electrical manufactures and textiles, were not greatly affected. But there was a dearth of the local supply of raw materials for them, and owing to loss of territory with its plant and population, her productivity was very greatly reduced. The deficit of coal alone was 50 million tons per annum. To make up for this would require doubling the output of the Ruhr coal mines, opening up new coalfields with consequent installation of new plant, machinery, and railways—a very difficult and doubtful proposition.

The output of the Ruhr certainly was increased, and very extensive development of the brown coal fields was commenced in Central Germany and south of Cologne. But the most effective improvement of the coal situation followed a close study of fuel economy throughout industry. In every way steps were taken to curtail the fuel demand by a general improvement of the efficiency of its use, and the construction of central power and heat stations, while wherever possible hydro-electric plants were installed.

As soon as the Ruhr was vacated by the army of occupation, the consolidation of the mines was commenced. Between 1924 and 1928 smaller mines, with an aggregate annual production of 16.7 million tons, were either closed or connected through to their larger neighbours. New mines were opened in the Northern Ruhr, and all were equipped with the latest machinery. Standardisation decreased the cost of equipment: the numbers of types of coal-cutting machines was reduced from 110 to 8, mining trucks from 155 to 3, with similar reductions of types of locomotives and even mine railway gauges. Notwithstanding
improvements in conditions of hours and employment, the output per man was increased by 28 per cent. on the pre-war value. As an example of the vast expenditure incurred on these renovations, the Harpener Bergbau A.G. spent over £4,125,000 between 1925 and 1929 on machinery, general equipment, rolling stock and coke ovens. Another mine, spending £470,000 in three years on mechanisation alone, increased its output per man by 40 per cent.

To Victorians perhaps the most interesting development in the German coal industry is the vast growth of the production of brown coal. Before the war a small amount was got out, mainly by hand. But now great quantities are removed by power shovels and special mechanical appliances like those recently imported from there for use at Yallourn. The mechanisation of this industry is so thorough that the probability of further improvement seems very remote. About 37 per cent. of the coal is used in central power stations. More than one-fourth of the brown coal is used in the chemical industries, partly for heat, partly for power; but increasing quantities are required for the extraction of their chemical constituents. One firm, the Badische Analin und Soda Fabrik, consumes annually no less than 2½ million tons. The total production of brown coal is now 17½ million tons annually. It is notable that this output exceeds the tonnage raised by all Germany’s black coal mines put together.

Returning to the black coal of the Ruhr, more than one-third of it is being converted to metallurgical coke. Formerly this process was wasteful. All by-products were lost. Prior to the War, however, by-product recovery ovens were being installed; yet most of the gas was wasted, or at least not put to the best use. Forty-five per cent. was consumed for heating the ovens; a similar amount was burnt beneath the boilers of the steel works and coal mines, and being regarded as of little intrinsic value, its combustion was not carefully controlled. Only ten per cent. was available for transmission to central power stations and for city distribution. In 1922, however, complete reorganisation was commenced. Obsolete plant was scrapped, and by-product ovens of higher efficiency were substituted, having deep, narrow ovens similar to those recently installed at Newcastle, New South Wales, and capable of completely carbonising a batch of coal in eleven hours instead of the eighteen to twenty-two hour periods of former models. In addition, many of these new ovens were equipped with double regenerators to enable them to be heated by the combustion of inferior fuels, such as blast furnace gas, or producer gas made from
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coke breeze or coal slack. About one-fifth of the ovens are already equipped in this manner, all the gas being available for transmission, and others will be converted as the demand for gas increases.

By these means, in the Ruhr alone, 28,000,000 tons of metallurgical coke are produced annually with the enormous evolution of over 352,000 million cubic feet of rich gas.

The problem of usefully disposing of this immense quantity of gas, which is more than three and one half times the total output of all Germany’s town gas undertakings, was entrusted to the Ruhrgas A.G., a subsidiary of the Vereinigte Stahlwerke A.G., which controls the coal mines, coke ovens, and steel works of the Ruhr. The Ruhrgas A.G. was founded with a capital of £1,250,000, and New York financiers, confident in the soundness of a proposal to transmit the gas to distant cities, took up a loan for a further twelve million dollars. After absorbing several smaller gas bulk distributing concerns, the company now has in operation 1240 miles of trunk mains, conveying gas throughout Western Germany, spreading from Aix to Hanover, and from the Dutch border of North Westphalia to Darmstadt in Hesse.

Elsewhere in Germany groups of town gas authorities, and also groups of coke oven proprietors have established bulk distributing companies. There is healthy rivalry among competing organisations, yet it is intended to interconnect all the systems. So far only eleven per cent. of the gas evolved in the Ruhr is transmitted beyond the border, but it is intended to distribute ultimately the whole of the production. Most of the steel mains vary between sixteen and thirty-two inches diameter, with some miles of thirty-six inch. Most of the latter is near Hanover, on a line which it is intended to extend to Berlin, a distance of four hundred miles from the coke ovens supplying the gas. Some of this is earmarked for power generation at Berlin, for the Germans recognise that the gas can be transmitted far more cheaply than the electric power that it could generate. Great quantities of gas are required also for the factories and industrial suburbs that are springing up like mushrooms around the great metropolis. Pressures run from forty-five to ninety pounds per square inch in the Ruhr, but farther afield they reach 300 or even 450 pounds. On the section of about 120 miles running between Ham and Hanover, which is designed for extension to Berlin via Brunswick and Magdeburg, pipes were installed for an ultimate pressure of 367 pounds per square inch. The economical distance between pumping stations depends on local circumstances, but it was
found to average about forty-three miles; they are generally equipped with reciprocating pumps driven by steam generated from local coke breeze or coal slack.

A great distributing organisation was formed to connect all the cities and towns of Bavaria, another for the whole of Saxony, while further projected lines connect Bremen-Hamburg-Lubeck-Kiel and Kassel-Thuringia and State of Saxony. Also a line is to run along the Rhine to Hesse-Baden-Wurtemberg-Augsburg and Nuremberg. Lastly, a company was formed to erect coke ovens near Magdeburg to supply that city and Dessau, the State of Anhalt, and the Prussian province of Saxony.

Simultaneously with the above projects there has been complete reorganisation of the public supply of electric power. New stations have been built at the mines, many using steam at very high pressures, and gradually all sources of water power are being utilised. All stations are being interconnected for mutual assistance by high tension transmission lines, so that already it is possible to furnish hydro-electric power from the Swiss Alps to consumers near the frontiers of Holland and Denmark, or to Berlin. In periods of low water flow, it is stated that power may be supplied from the stations of Middle Germany, consuming brown coal, to the Alpine provinces; and even, via Baden, right across the border into Switzerland. Electricity may be transmitted from the Ruhr to North-Eastern Prussia. Most of the large factories having excess power as a by-product are being connected into the net. Even in the mountain villages the local torrents have been harnessed to supply power for the home and the small village textile factory, specialising in some particular class of fabric. Over two and one half million horse power is absorbed in the agricultural districts lying between the great industrial belts. It was found that this load, although subject to seasonal fluctuations, was useful in conjunction with electro-chemical works in building up a load suitable for superpower stations with their distant transmission lines.

The most important water power plants are in Bavaria. A recent example is the project of the Mittlere Isar A.G., where a canal, drawing water from an artificial basin fed from the Isar River, near Munich, conducts it through 33 miles of country; although only a fraction of the river flow is conveyed through the canal, a total of 81,560 kilowatts are generated in the four power stations on the canal.

Always with an eye to economy, great sums have been spent in Germany since 1924 on pumped-water power-storage systems.
In order to balance the loads on thermal power stations, water is pumped at periods of low electrical demand from low-lying reservoirs to storage basins in the mountains, and during periods of greater electrical demand it is allowed to flow back through water turbines to generate the required power. Some of these installations serve to equalise the hourly demands, but others are seasonal in operation. Although the efficiency of these installations is only 70 per cent., they are considered commercially economical. The machinery consists essentially of a centrifugal pump, direct coupled through a hydro-mechanical clutch to an electric synchronous motor, which is capable also of acting as an alternator; the alternator in turn is coupled to the water turbine, or pelton wheel. What is claimed to be the largest pump in the world was constructed for one of these plants—for the Niederwartha power storage scheme near Dresden. The pump has a capacity of 140,000 gallons per hour at 490 feet head, and requires 27,000 horse power to drive it. Ultimately there will be four of these units, and the turbines will furnish 120,000 horse power. The water is recirculated between two reservoirs, each of capacity 38,540 acre feet, giving a power storage of approximately thirty million units.

In some respects the most interesting of recent hydro-electrical undertakings in Germany is the Schluchsee project, where the Schluch Lake is being dammed, raising the water level 98 feet to provide a storage capacity of 87,480 acre feet. The fall therefrom to the Rhine is 1946 feet, to be divided into three steps, respectively 660 feet, 925 feet, and 361 feet. At each step the waters of lower tributaries are added, and in times of low demand the energy from the flow of these streams will be stored by pumping water into the high level lake. This extraordinary procedure was adopted apparently because of the impracticability of storing the water of the tributaries. The plant when complete will have a maximum output of 390,000 kilowatts, and an annual output of five hundred million units, more than half of which will come from the tributaries. The generators are coupled to 41,000 horse power Francis turbines. The pumps will be placed at the base of the vertical shaft, and the overall height of the machinery will be as much as eighty-two feet. The main penstock, which is three and three-quarter miles in length, has a bore of thirteen feet four inches. The storage capacity alone of this undertaking is roughly two hundred million units, or more than eight months' average output of Yallourn.

Some idea of the immensity of Germany's recent activities in the electric power field may be gleaned from the fact that power storage projects inaugurated since 1924 aggregate over
880,000 horse power in their turbine, and it must be borne in mind that these installations are only appendices of other power projects. Moreover, water power constitutes only one-eighth of the energy generated by public authorities. Even the conveyance of power from Scandinavian hydro-electric stations via an extra high tension submarine cable is contemplated.

The great steel works of Germany have now been concentrated in the Ruhr, where most of the coke from the by-product ovens is being consumed in the blast furnaces. Forsaking the “minette” iron ore deposits of Lorraine, the Germans imported richer ores from Sweden, Spain, Newfoundland, and Algiers. A greater proportion of scrap is used, thus further economising in fuel. Even the metal salvaged from their navy sunk in the Scapa Flow was sought for this purpose. To further conserve the fuel, new blast furnaces were erected, each having a capacity exceeding 1000 tons of product per day, and new steel works were laid out on most modern lines so that the hot, crude metal from the blast furnaces was transferred directly to the open-hearth furnace or converter, and every mechanical device was installed to reduce labour. All waste heat and waste gases are utilised in soaking pits, furnaces, and waste heat boilers, the last mentioned providing power often in excess of that required for the mills. A mill at Hamborn, for instance, generates annually from waste heat boilers over two hundred million units. By these improvements the fuel consumed per ton of output has been reduced in various works by 30 per cent. to 70 per cent., and the labour by 37 per cent. on pre-war figures. It is estimated that to attain these improvements in the steel industry over £50,000,000 has been spent during the last five years.

In order to carry out these works with maximum economy the various coal mining, coking, and steel interests of the Ruhr were brought together, and an association called the Vereinigte Stahlwerke A.G. was formed on the lines of the United States Steel Corporation. All the by-products of the tar and ammonia from the coke ovens are worked up by the Ruhrchemie A.G., which is a subsidiary of the above organisation.

The participating bodies tended each to specialise in some line most suitable to its plant and geographical position, one yielding to another the market for a particular commodity in exchange for that of another—billet, bars, and blooms to be made in one place, wire to be drawn in another—all to conserve national effort. This tendency towards specialisation is evident throughout German industry. For instance, the Demag has taken over from many firms the markets for mining plant, machinery, and large engines in exchange for markets for unfinished products previously handled by them. Similarly the
A.E.G. has concentrated on machinery and electrical goods, yielding in exchange markets for other products formerly on their list.

The same co-operative tendencies are visible also among the smaller manufacturers handling special lines of machinery and instruments, where each firm tends more and more to concentrate and to improve the efficiency of its design and methods in a narrower field of effort. For example, five firms making machinery for flour mills, while preserving their individual identity, agreed each to confine its activities to the construction of special portion of the mills, and thereby improve the design and methods of construction. Committees for standardisation secured the reduction of types of machines, resulting in further economies in manufacture. For example, a firm making printing machines, by greatly reducing the number of sizes and patterns of its machines, is claimed to have increased its output per man by forty per cent.

Innumerable examples of specialisation by co-operation could be cited, all tending to improve the skill of the specialist, and at the same time to enable the small proprietor to maintain his individual existence. This admirable readiness to co-operate for a common benefit is a most notable feature of recent industrial development all over the world; but Germany is a convenient example, because there those activities are in some respects more easily traced than those of any other country.

In conclusion, it is of course obvious that conditions in a new country, of vast extent and sparsely settled, are different from those prevailing in densely populated countries like Germany. But with necessary variations the policies outlined are applicable anywhere, and a selection has been made of facts illustrating principles likely to be of use to those, who, with a knowledge of local financial conditions, and possessing the necessary ability, are in a position to determine the course of future developments in Australia.