The map of medieval England is dotted with famous fields, scenes of victories and defeats which shaped the history of Europe and perhaps of the world. But none had a more widespread or lasting influence than the events which took place on nameless battlefields of the last two centuries, scattered across the Midlands and the North, with their crumbling fortresses and their rusting arms.

They were the battlefields of a revolution led by a relative handful of resourceful, determined men, whose fortresses were the factories and iron foundries, and whose weapons were the machines and tools which helped them fashion the Industrial Revolution. Under the smokescreen of their belching blast furnaces, the captains of industry - the ironmasters and engineers - invaded the green vales and forests, and they transformed that idealised portrait of 'Merrie England' into the world's workshop. Their victory left few lives untouched anywhere, either then or since and more than two centuries later we are still trying to digest and deal with the consequences.

One of the enduring questions about the Industrial Revolution is why it should have begun in England, when the conditions which brought it into existence were also to be found in many other countries in western Europe. It was, however, the British who in the middle of the eighteenth century began a spectacular advance from their bucolic past. They generated a self-sustaining wave of vigour that within a hundred years had won them the greatest empire ever seen, and made Britain the dominant world power.

Regardless of any political or intellectual contributions to that worldwide upheaval of traditional ways of life, it is now clear that Britain provided two of the most vital practical impulses: a method of producing iron in virtually unlimited amounts, and the world's first source of energy other than the natural forces of wind, water and living muscle - the steam engine. Ironically, both these advances were brought about by necessity. They grew from the constraints imposed on the
The battlefields of the Industrial Revolution are dotted across the once 'green and pleasant land' which they converted into the world's workshop. Chatterley Whitfield colliery in Staffordshire, once one of Britain's most productive coal mines, is now a mining museum.

The demand for charcoal by the iron-making industry in the Middle Ages led to a decimation of the forests, and brought on Europe's first great 'energy crisis'. One of the last of the charcoal-burners at work in a valley in southern Austria.

countries of Europe by a problem which has returned to find a place in our own vocabulary: an energy crisis.

Both cause and consequence of that first European energy crisis can still be seen in the quiet valleys of southern Austria, where one or two charcoal burners are still practising their craft. As their predecessors have done for millennia, they stack their timber into piles and by a simple but subtle process turn it into a clean, smokeless fuel.

Charcoal making is a practice whose origins go back to man's first
experience with fire, and the observation that partly-burned wood makes a more versatile fuel than wood itself. The slow, controlled combustion in the confined atmosphere of the charcoal stack drives off water and volatile elements, leaving an almost pure carbon which burns with a hot, clean glow. That discovery began one of mankind’s more devastating assaults on the environment: the cutting of trees to make charcoal.

At first, no doubt, charcoal was used almost exclusively for cooking and heating, as people began to live in enclosed spaces, such as caves and huts. But when metals began to come into daily use the consumption of charcoal must have increased beyond all expectation. For the melting and working of native metals, such as gold and copper, charcoal was ideal, since it provided a source of intense heat even in a small crucible. For the large-scale smelting of copper, lead, silver, iron and other metals from their ores, charcoal was essential.

Across the ancient world, as the Bronze Age got under way, the forests around every mining area were decimated. The results can still be seen along all the shores of Mediterranean, where stands of oak and cypress once came right down to the sea. By the end of the Roman era the slopes were as bare and rocky as they are today. In some extreme cases, such as the copper-rich island of Cyprus, three thousand years of smelting saw virtually the entire island cleared of its trees to fuel the smelters.

After the stagnation of the Dark Ages the forests of western Europe came under even more sustained attack. The renewal of economic activity, the growth of populations in towns and cities, and, finally, the steady rise in the output of iron – all these created demands for energy
that could only be met by the making of charcoal. At the same time, there was an expansion of farming to produce food for the growing populations, and a corresponding contraction in the areas left under forest.

A glimpse of what Europe must have been like at this time, on the threshold of the Industrial Revolution, can still be obtained in the mountains of Styria, in southern Austria. This major iron and steel-producing region is centred on the huge 'mountain of iron', the Erzeberg, which for hundreds of years has been carved away in terraces, like a monstrous layer cake. In the quiet valleys nearby there are scenes of pre-industrial life which elsewhere in Europe have for the most part been swallowed up by the growth of cities.

The little village of Vordenberg, for example, is dominated by a solid yellow brick and stone building which contains the last of a succession of fourteen iron furnaces which worked in the valley from medieval times until the beginning of the present century. In its general design the Vordenberg furnace had its counterparts all over Europe. It was fed from the top with iron ore and and charcoal, and it needed a huge amount of charcoal to smelt a single tonne of iron. The method was profligate. It was the appetites of these furnaces which devourd the forests on the once densely timbered slopes around Vordenberg, and turned them into alpine meadows.

These effects were felt all over Europe, but the first country to reach crisis point over the shortage of wood and charcoal was Britain, for two main reasons. One was the limited area of the British Isles themselves and of their forests. The other was the proportionately more rapid growth of population in Britain than anywhere else in Europe. In England and Wales, between 1530 and 1690, the population nearly doubled, from three million to just under six million. There was also a widespread move into cities, especially London, whose population multiplied eight times over that same period, from sixty thousand to more than half a million, which made it the largest city in Europe and perhaps in the world. Larger towns and cities meant heavier consumption of wood from surrounding areas, and soaring costs for fuel and timber for construction. During the Elizabethan period in England wood prices rose very much faster than those of any other commodity.

The wood shortage was exacerbated by the growing demands of the iron-making industry. This problem became acute after the development, in the fifteenth century, of the means of turning out cast iron in quantity. This was achieved by the harnessing of waterwheels to large bellows, to increase the supply of air to the furnaces. The earliest known water-powered blast furnace in Europe began operating at Ferriere in Italy in 1463. From that time onwards the new technology spread rapidly, especially when it was found that cannons could be cast from iron instead of bronze, which was expensive. At the same time, tools, agricultural implements, and household utensils were still being produced from wrought iron, made in bloomery furnaces. Between the blast and bloomeries, the consumption of charcoal in England reached massive proportions. The effects can still be seen in one area where iron making flourished – the Weald of Kent.
The Weald today is a broad expanse of gently rolling hills and vales, a patchwork of fields and hedgerows, with scattered woods and copses. Some of the fields are under pasture, and carry herds of dairy cattle. Others grow the hops for which Kent is famous, and the spires of the village churches are echoed by the tall conical roofs of the oast-houses, where the hops are dried. The low profile of the Weald has a timeless, unchanging look. But this is deceptive. The landscape today is not the original countenance of this part of southern England.

Once, the Weald was densely forested with mature oaks, beech and chestnut. But the forests of the Weald stood on chalk, and in the chalk, beginning in Roman times, rich pockets of iron ore were found. In almost every surviving patch of woods there are shallow pits, where first the Romans, then the Saxons, and later the iron makers of medieval England dug out the iron. To smelt and forge the iron, however, the ironmasters needed charcoal — and so began the clearance of the forests.

By the sixteenth century the Weald was dotted with blast furnaces and forges, each surrounded by an expanding patch of cleared land. Most of the furnaces were built beside small streams, and power was provided by a waterwheel, driven by water stored in a small dam. A typical site lies at the foot of Furnace Lane in the village of Brenchley. The foundations of the wheel and its waterway can still be seen in the stream bed beside tree-lined banks. The dam, overhung with willows, now provides carp fishing for the villagers. The cannons cast here were so famous that they were exported to many countries across the Channel. There is an echo of that trade in the name of the Gun and Spit-Roast Inn in Brenchley.

However, as the iron industry grew it generated not only trade but conflict. The forests of Britain had long been admired for their most celebrated inhabitants, slow-growing and long-lived. These were the mighty oaks, which for centuries had provided the wooden walls of old England. The crucial importance of the sea defences of the British Isles was first acknowledged by Henry VIII, who in effect founded the Royal Navy, and built the first Royal Dockyard at Portsmouth. In that dry dock lies the most majestic survivor of a long line of wooden warships reaching back to Alfred the Great – HMS Victory, Nelson’s flagship at the Battle of Trafalgar. She contains two thousand one hundred tonnes of oak. Thousands of trees – a whole forest – had to be cut for a ship of the line like Victory, and the same huge tonnages of timber were needed for the ships of the growing maritime trade.

So two uses of oak were in conflict. And now a third industry added its demands to the pressures on the forests: glass making. Such was the demand for window glass in the sixteenth century that scores of glass makers from Europe crossed the Channel to England and set themselves up in business in the forests, where they found timber for their furnaces. The government was finally forced to act.

In 1558 a law was passed forbidding ‘the felling of trees to make coals for the burning of iron’, but the Weald of Kent and Sussex was exempted, perhaps because of lobbying by the thriving iron industry in that area. And still the price of wood continued to climb. In 1559 a
writer complained that the price had risen from a penny to two shillings a load 'by reason of the iron mills'. By 1581 the shortage of wood for ship building was so serious that a further act was passed, forbidding the felling of trees within twenty-two miles of the Thames, within four miles of the great forests of the Weald, and within three miles of the coastline, anywhere. This decree effectively wiped out the iron-making industries of the Weald, but the consumption of wood by the glassmakers continued, and so did the domestic demand from city dwellers.

By 1615 England was facing an energy crisis. A Royal proclamation in that year lamented the disappearance of the kind of wood 'which is not only great and large in height and bulk, but hath also that toughness and heart, as it is not subject to rive or cleave, and thereby of excellent use for shipping'. And so, at last, that country was forced to turn to a source of fuel which had been known for centuries, but which few had chosen to use: coal.43

It is impossible to say when coal was first burned deliberately. It made little contribution to the technologies of the ancient world in the Near East or the Mediterranean, because there were no large outcrops of coal in those regions. The first recorded accounts of the regular use of coal as fuel come from China, during the Han dynasty (206 BC to AD 220). The Chinese seem to have been consistent users of coal for millennia, because Marco Polo, on his return to Italy from China in the thirteenth century, reported that in places the people burned 'black stones' for fuel.

The first known use of coal in Europe was in Britain, during the Roman occupation, when pieces were picked up on the sea shores, and particularly along the Firth of Forth in Scotland. Because of this association it was called 'sea coal', although we know now that it had been broken away by the waves from the seams which outcropped along the coast. Once the Romans left in the fifth century AD, however, coal seems to have been forgotten for centuries.

There were attempts to use coal for heating houses after the Norman conquest of Britain, but the sulphurous fumes and smoke were intolerable in ordinary houses, which at that time had no chimneys. The fireplace was simply a depression in the middle of the floor, and at a certain time each night, at the ringing of a bell, the fire had to be put out by being covered - the couvre feu in French, which became curfew. In succeeding centuries, however, as the price of wood, charcoal and peat rose, there was a renewed interest in coal, especially when houses began to include fireplaces and chimneys.

By the Middle Ages the British had become the world's largest users of coal. Rich seams had been discovered in many parts of England, Scotland and Wales. Many industries, heavy users of fuel, had converted to coal because of the cost of charcoal. For some, such as glass making, this had been made possible by a significant advance in technology: the development in 1612 of the 'reverberatory' furnace. In this, the materials to be heated were not mixed with the fuel, as previously, but placed in crucibles at one end of a tunnel-shaped furnace, near the chimney. The hot gases from the burning coal passed through the tunnel, and heat was reflected from the arched brick roof on to the