

Pearson BTEC Levels 5 Higher Nationals in Engineering (RQF)

**Unit 44: Industrial Power,
Electronics and Storage**

Unit Workbook 1

in a series of 4 for this unit

Learning Outcome 1

**Energy Demand and its Influence
on the Technology and Methods of
Energy Production**

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Sample

INTRODUCTION

Evaluating energy demand to determine the technology and methods of energy production.

Energy demand:

- Historical energy production, energy consumption, environmental aspects and global warming.
- The need for energy systems and global energy demand over the short to long term.
- Environmental effects associated with energy generation and consumption.
- Practicality, benefits, drawbacks and effectiveness of renewable energy sources.
- Overview of renewable energy technologies (wind, solar, bio, hydro, geothermal) and the associated costs.
- Future energy trends, scenarios and sustainable energy sources.

Sample

GUIDANCE

This document is prepared to break the unit material down into bite size chunks. You will see the learning outcomes above treated in their own sections. Therein you will encounter the following structures;

Purpose

Explains *why* you need to study the current section of material. Quite often learners are put off by material which does not initially seem to be relevant to a topic or profession. Once you understand the importance of new learning or theory you will embrace the concepts more readily.

Theory

Conveys new material to you in a straightforward fashion. To support the treatments in this section you are strongly advised to follow the given hyperlinks, which may be useful documents or applications on the web.

Example

The examples/worked examples are presented in a knowledge-building order. Make sure you follow them all through. If you are feeling confident then you might like to treat an example as a question, in which case cover it up and have a go yourself. Many of the examples given resemble assignment questions which will come your way, so follow them through diligently.

Question

Questions should not be avoided if you are determined to learn. Please do take the time to tackle each of the given questions, in the order in which they are presented. The order is important, as further knowledge and confidence is built upon previous knowledge and confidence. As an Online Learner it is important that the answers to questions are immediately available to you. Contact your Unit Tutor if you need help.

Challenge

You can really cement your new knowledge by undertaking the challenges. A challenge could be to download software and perform an exercise. An alternative challenge might involve a practical activity or other form of research.

Video

Videos on the web can be very useful supplements to your distance learning efforts. Wherever an online video(s) will help you then it will be hyperlinked at the appropriate point.

4. ENERGY DEMAND

4.1 Introduction

Energy has always been among the most fundamental elements for the survival, reproduction and evolution of human society. The sun is the ultimate source of energy. Non-renewable fossil fuels are formed by solar energy that has been captured over extremely long geological periods. What is more, renewable energy sources are directly (photovoltaic systems) and indirectly (wind, water, etc.) interrelated with the sun. Inevitably, almost all organisms rely, either directly or indirectly, on solar energy for their survival and maintenance. Life on earth would be impossible without the photosynthetic conversion of solar energy into plant biomass. The sun provides approximately 1366 watts per square meter per second ($\text{Wm}^{-2}\text{s}^{-1}$), hence, about 170,000 terawatts ($\text{TWm}^{-2}\text{s}^{-1}$) on the Earth's surface. In the food chain, solar energy flows are captured and converted through the complex process of photosynthesis. Part of this energy is used by organisms, while a great proportion is lost as heat and a small portion is passed down the food chain as one organism digests another. Apart from the food chain, intelligent human systems utilize the solar energy embodied in fossil fuels and the renewable energy sources as the essential power, the "engine" of modern civilization. This Workbook concentrates on electrical energy, its collection, its storage, its delivery, its application by human societies, and on the power electronic devices which are utilised in these endeavours.

Please bear in mind that with the continued introduction of renewable energy sources and the retirement or moth-balling of existing energy sources, some of the statistics provided in this Workbook may appear some years out of date. However, where statistics are provided, year of derivation and source are usually referenced. Remember that when you research answers to the assignment questions you will face the same problem. This makes it especially important that all reference material is cited correctly.

4.2 Historical Energy Production

Throughout recorded history, humans have searched for ways of putting energy to work for them. They found ways of growing food instead of foraging for it out in the wild. Instead of walking, they ride in cars they have built for getting from one place to another. Humans even learned how to send messages electronically instead of using a messenger or a postal service. This quest for faster, easier, and more efficient ways of meeting the needs of a growing human population has led to increasingly high energy demands. But the resources currently used for generating energy are running out. The pollution created by the use of these resources is also causing significant damage to the planet's natural systems. For these reasons, people are beginning to turn to alternative energy sources to reduce pollution while meeting their energy needs.

4.3 The Organic Energy Economy

The sun is by far the oldest source of energy. It has provided heat and light for millions of years and is directly responsible for sustaining all life on earth. Energy, in almost all its forms, starts with the sun. For example, wind is created by temperature changes caused by the sun. Plants and trees, which provide energy in numerous ways, gain their nourishment from the sun. Streams and rivers, providing energy by the force of their downhill flow, are formed from rain and snow. Rain and snow fall at high elevations after being evaporated from lakes and oceans by the sun. The variety of life-forms depending on the sun's energy in one manner or another is impressive.

Although the sun provides vast quantities of energy in many forms, humans could not control it, and so they began to explore other sources of energy. For example, humans discovered a way to generate their

own energy from wood, somewhere between five hundred thousand and seven hundred thousand years ago, by most scientists' estimates. The very first milestone of mankind's utilisation of energy was the mastery of fire. The utilisation of fire for cooking and heating, using biomass (mainly wood) as fuel, dates back at least 4–500,000 years (Ref 1). At first, wood was burned for warmth, security, light, and for preparing food. The burning of wood and other forms of biomass eventually led to the discovery of ovens which, besides cooking, permitted the early forms of crafting. Ovens made it possible to produce pottery and to refine metals from ore. Early humans lived a largely nomadic existence, closely in synchrony with the change of seasons and periodic plant growth.

The next milestone of mankind was the Agricultural Revolution (Ref 2). The introduction of agriculture increased the amount of available food, permitting the first permanent human settlements, which caused a substantial increase of human population. Water and wind power were the next essential steps in the evolution of the human conquest of energy. The watermill was invented about 2500 years ago (Ref 3). Using both the water and the windmills, humans managed to master the water and air power necessary to meet their needs for crushing grain (wheat, etc.) in order to produce flour, crushing olives for olive oil production, tanning leather, smelting iron, sawing wood, and so on (Ref 4). However, despite the improvements in energy use and the exploitation of several energy resources, the rapid growth of population in Europe about a thousand years ago, as a result of this progress, led to dramatic pressures on land for cultivation, and forests were being encroached upon to provide more land (Ref 5 and Ref 6).

As the human population increased over time, so did humanity's dependence on fire. This increase in population led to severe shortages of wood in some areas of the world. By the sixteenth century, for instance, Great Britain had so few trees left because of overcutting that people had to search for new sources of fuel. This first era of mankind's quest for new energy resources, from the early discovery of fire to the agricultural (and farming) revolution, could be briefly described as the Organic Energy Economy (Ref 7). This solar-based energy economy was intimately based on intensive land use and biomass consumption. Inevitably, the organic energy economy was limited to the consumption of energy at the rate that solar energy can be converted into useful goods and services. In this context, population growth and the limited land availability imposed crucial restrictions upon further economic growth and gradually forced a transition towards a new energy regime, the era of fossil fuels (Ref 7 and Ref 8).

4.4 Transition to the Fossil Fuel Economy

The milestone that determined the transition from the organic economy to the fossil fuel (because they are extracted from fossilized plant and animal material from deep under the ground) economy, was the invention that characterized the Industrial Revolution era, was the steam engine. The unique process that the steam engine initiated was the conversion of chemical energy (heat) into mechanical energy (motion) (Ref 9). The biomass energy stocks accumulated in the earth's crust for hundreds of millions of years were now available to serve human needs for the first time in mankind's history, to such an extent that the dawn of the fossil fuel era was about to begin. While the early steam engine was mainly used for pumping water out of coal mines, it soon became, thanks to the efficiency improvements made by James Watt, a Scottish inventor and mechanical engineer, a valuable tool which increased human muscle and animal power for extracting more coal, drove the manufacturing industry, moved ships and trains, and laid the foundation for today's complex and energy intensive human (economic) systems (Ref 7).

Although coal had been used in different parts of the world since the second millennium BC, its potential uses had not been fully explored. During the 18th century, many industries had already substituted wood-fuels with coal, while heating services made the transition from organic biomass to fossil fuels by the beginning of the 19th century. Specifically, between 1650 and 1740, the real prices of wood-fuel increased

substantially, which encouraged its progressive substitution with coal (Ref 10 and Ref 7). The timing of this substitution was absolutely essential, given the fact that during the second half of the 17th century the harvesting of forest trees had to be regulated, even restricted, in England and elsewhere in Europe (Ref 5). It has been suggested that, by 1800, had the British economy been dependent on wood-fuel, a surface area equivalent to the whole of Britain would have had to be coppiced every year in order to supply the energy demands of the economy. In 1800, wind and water power provided only one-tenth of the total power of the British economy (Ref 6). By 1900, steam engines provided two-thirds of all power services and the expansion of the railway network provided more than 90 % of goods transportation on land, while steam ships were carrying about 80 % of all freight cargos at sea.

Once coal replaced wood as a fuel, inventors found many ways that coal could be used as a source of energy. The Industrial Revolution marked a big change for people of the world. Many of the agricultural societies that used human muscle power and animals to do work quickly became industrialized and began using machines to do work. When the coal-burning steam engine was invented, a race began to create and build bigger, better, and faster machines. The machines were used to provide transportation and to do the work formerly done by people and animals. Coal continued to be used in great quantities until the twentieth century. Then came the invention of the internal combustion engine and the automobile, which used oil and gas instead of coal. Over the years automobiles were modified to use oil and gas more efficiently and with less pollution, but the sheer numbers of automobiles that have come into use over the years have offset the potentially positive impact of these changes. Oil and gas also came into use in other areas, such as for manufacturing and power production, and remain in high use today.

Ever since the Industrial Revolution, humans have sought to generate power from a variety of energy sources. This remains true today, especially as some energy sources are being used up. Current power needs are continuing to climb while the resources of the planet are steadily being depleted. Technology that operates on electricity, including everything from the typical refrigerator in the kitchen to street lights, is now a part of the lives of most people in industrialised nations. Much of that electricity is generated in power plants, which use large quantities of fossil fuels.

The process that created fossil fuels is a natural process of the earth's systems. The remains of plants and animals that died millions of years ago were slowly buried under sediment from the earth and compressed by the weight of the sediment. Over the course of millions of years, the pressure of being compressed by the sediment turned the dead plants and animals into oil, coal, and natural gas. The earth took 500 million years to produce these fuels. Humans have severely depleted them in just over one hundred years, a rate that is 50 million times greater than the rate at which they are formed.

There are three primary types of fossil fuels: coal, oil, and natural gas. Coal is responsible for providing much of the energy for producing electricity.

For most purposes, oil can be considered as liquid coal. Oil is usually found underground in dome-shaped spaces directly above coal deposits. Much of the oil extracted each year is used in transportation as either lubricant or fuel.

Natural gas is highly flammable and is made up mostly of methane, created from large amounts of plant material that did not become coal. Natural gas will usually flow from a drilled well under its own pressure. Natural gas is used primarily for heating purposes and for powering industrial production, especially in manufacturing.