**С. С. Никипорець, Н. В. Герасименко, С. О. Кот,
Л. Е. Габрійчук**

English for power engineers

Англійська мова для енергетиків

Міністерство освіти і науки України
Вінницький національний технічний університет

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Англійська мова для студентів-енергетиків

Навчальний посібник

Вінниця
ВНТУ
2021

УДК ……..
ББК ……
Н.

Рекомендовано до друку Вченою радою Вінницького національного технічного університету Міністерства освіти і науки України (протокол № 10 від 23.03.2021 р.)

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Навчальний посібник призначений для студентів 1 курсу енергетичних спеціальностей та складається з 10 розділів, в яких наведено базові поняття енергетики, такі як «електричний струм», «електричне коло», «провідники та ізолятори», «трансформатори», «електродвигуни», «генератори» тощо. В посібнику надаються тексти з комплексом вправ на розвиток та закріплення різноманітних комунікативних компетенцій. Тематичний словник-мінімум допоможе студентам-першокурсникам опанувати необхідну професійну лексику.

УДК ….
ББК ….

ЗМІСТ

UNIT 1.

Text 1. *ELECTRIC CURRENT*

We cannot imagine modern civilization without *electric current*. Electric lamps, trams and trains, radios, TV sets and many other electrically operated devices are widely used today.

We know numerous applications of the electric current. Take, for example, an *electric motor*. The electric motor transforms electric energy into mechanical energy. It finds application at every plant and factory.

We know *two* kinds of the electric current – ***alternating*** current and ***direct*** current. The *unit of measure* for current is the *ampere*. The electric current is the motion of electrons along the circuit. A stream of electrons in a circuit develops a magnetic field around the conductor.

I. Translate into English:

електричний струм, провідник, поле, електричне коло, постійний струм, змінний струм, потік, рух, одиниця вимірювання, пристрій

II. Answer the following questions:

1. What applications of electric current do you know?
2. What device transforms electric energy into mechanical energy?
3. What two kinds of electric current do you know?
4. What is the electric current?

III. Translate into Ukrainian:

1. There is a strong magnetic field around this conductor.
2. Battery transforms chemical energy into electrical energy
3. You must use direct current in your experiment.
4. Metals are good conductors of electric current.
5. We have many electronic devices in our laboratory.

Text 2. ***ELECTRICITY SERVES MAN***

1. Pay attention to the pronunciation of the following words:

vacuum ['vækjuːm] — вакуум

TV-set — телевізор

southern ['sʌðən] — південний

process ['prəuses] — процес

routine [ru'tiːn] — рутина

refrigerator [rɪ'frɪʤ(ə)reɪtə] — холодильник

2. Words and expressions necessary to understand the text:

obedient — слухняний

to turn a switch — повернути вимикач

to operate — приводити в рух

fan — вентилятор

razor — бритва

appliance — прилад

kitchen unit — кухонний комбайн

to amalgamate — об'єднувати

to affect — впливати

production control – управління виробництвом

to automate — автоматизувати

electroslag — електроокалення

service life of bearing – термін роботи підшипника

evaluation — оцінка

Geiger counter — лічильник Гейгера

to run — приводити в рух

flaw — тріщина, брак

available — наявний

all-round — всебічний

All around us – in the factory shop, or laboratory and at home — we find an obedient force ready to serve us in some way. It is *electricity*.

Electricity (electric power) has become so much a part of our daily life that we seldom think of its importance. All you have to do is turn a switch and electric devices will be doing their job for you.

Electric motors operate washing machines, refrigerators, vacuum cleaners, electric razors and many other electric *appliances*. The range of household electric appliances is growing. Today an increasingly greater number of people are using TV-sets, refrigerators, washing machines, electric cookers, and kitchen units, as well as air-conditioners in the southern regions of the country.

Electricity made possible the engineering progress of today. Electricity serves as the basis of modernizing industry, amalgamating capacities, increasing *equipment efficiency*, mechanizing and automating processes and concentrating production.

Electricity not only tremendously increases man's power but it becomes an inseparable part of *technology*. Not long ago, electricity affected the objects of labour mainly indirectly. It was a motive force, provided favourable conditions for processing or machining. Now it is becoming a processing or machining element itself as well as the basis of *automatic production control*.

For instance, the service life of bearings made by *electroslag remelting method* extends almost three times as compared with the same bearings made of conventional steel.

And think of the role of electricity for communication or automation! It is used to transmit and process information. It is the basis of the comprehensive automation of all production process — technology, management, regulation, control and evaluation. Electricity does not merely make work easier: it changes it completely. Electricity is the basis of *electronics*, which is doing much of the routine brain work.

Little could be done in modern *research laboratory* without the aid of electricity. Nearly all the measuring devices used in developing nuclear power are electrically operated. Geiger counters which detect the presence of uranium ores in the earth are run with batteries. X-ray machines, which depend upon electricity, are used in industry *to detect flaws* in metal.

Much of today's scientific research depends on the *solution* of difficult mathematical problems, some of which would require days and months to solve by the usual methods. Electrically operated computers now make the answer to these problems *available* in seconds.

Thus, electrification is not only a means to *achieve* the highest productivity of labour. It is also directly responsible for releasing man's spiritual and physical energy, which will be used for his all-round harmonious development.

I. Read the sentences, translate them into Ukrainian and decide if they are true (T) of false (F).

1. Electric motors operate washing machines, refrigerators, vacuum cleaners, electric razors and many other electric appliances.
2. Without electricity the engineering progress of today is quite possible.
3. Electricity is used to transmit and process information.
4. We can do a lot in modern research laboratory without the aid of electricity.
5. X-ray machines are used in industry to detect flaws in metal.

II. Put the words given in A find the Russian equivalents in B.

A	B
available	всебічний
refrigerator	слухняний
razor	прилад
obedient	електроокалення
flaw	вентилятор
fan	оцінка
electroslag	холодильник
appliance	бритва
evaluation	тріщина, брак
all-round	об’єднувати
amalgamate	наявний

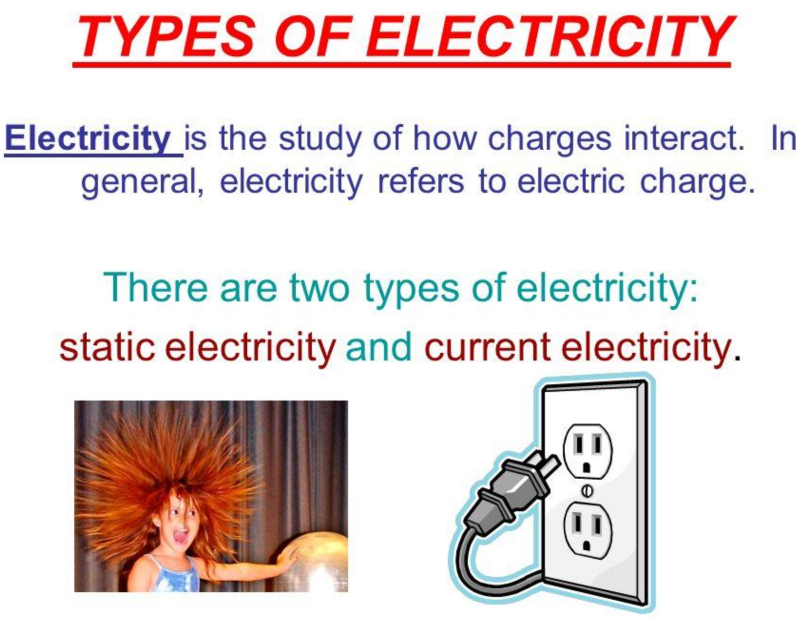
III. Answer the following questions:

1. a) Where do we find an obedient force ready to serve us in some way? b) What do we call this force?
2. What do electric motors operate?
3. What is the role of electricity for communication or automation?
4. What do we use X-ray machines in industry for?

UNIT 2.

Text 1. ***TYPES OF ELECTRICITY.***

There are two types of electricity – electricity ***at rest*** or *in a static condition* and electricity ***in motion*** or the *electric current*. Let us first consider static electricity.



More than 2,500 years ago, the Greeks knew how to get *electricity* by rubbing substances. But they could not use it, because static electricity is usually very high in voltage and difficult to control.

We know that an electric current is a flow of electric charges along a conductor. It may be produced by means of a *battery* or by means of an *electric generator*.

The battery is a device which transforms *chemical energy* into electrical energy and the generator transforms *mechanical energy* into electrical energy.

I. Find the correct definition out of the three given below.

1. The motor changes electrical energy into

a) *heat energy*, b) *chemical energy*, c) *mechanical energy*.

2. The generator changes mechanical energy into

a) *chemical energy*, b) *electrical energy*, c) *light energy*.

3. The battery changes chemical energy into

a) *solar energy*, b) *heat energy*, c) *electric energy*.

I. For the words given in A find the Ukrainian equivalents in B.

A	B
1. flow	1. речовина
2. rubbing	2. поле
3. to produce	3. потік
4. substance	4. пристрій, прилад
5. field	5. постійний струм
6. motion	6. виготовляти
7. circuit	7. рух
8. direct current	8. тертя
9. charge	9. заряд
10. device	10. електричне коло

Text 2.

ELECTRICITY

It is impossible to imagine our civilization without *electricity*: economic and social progress will be turned to the past and our daily lives completely transformed.

Electrical power has become universal. Thousands of applications of electricity such as *lighting*, *electrochemistry* and *electrometallurgy* are longstanding and unquestionable.

With the appearance of the electrical motor, power cables replaced transmission shafts, gear wheels, belts and pulleys[1] in the 19th century *workshops*. And in the home a whole range of various time and labour saving appliances[2] have become a part of our everyday lives.

Other devices are based on specific *properties of electricity*: ***electrostatics*** in the case of photocopying machine, and ***electromagnetism*** in the case of radar and television. These applications have made electricity most widely used.

The first industrial application was in the silver workshops in Paris. The ***generator*** — a new compact *source of electricity* — was also developed there. The generator replaced the batteries and other devices that had been used before.

Electric lighting came into wide use at the end of the last century with the development of the *electric lamp* by Thomas Edison. Then the ***transformer*** was invented, the first electric lines and networks were set up, dynamos and induction motors[3] were designed.

Since the beginning of the 20th century the successful *development* of electricity has begun throughout the industrial world. The *consumption* of electricity has doubled every ten years.

Today consumption of electricity per capita[4] is an indicator of the state of development and economic health of a nation. Electricity has replaced other sources of energy as it has been realized that it offers improved service and reduced cost.

One of the greatest *advantages* of electricity is that it is clean, easily regulated and generates no by-products[5]. Applications of electricity now cover all fields of human activity from house washing machines to the latest laser devices. Electricity is the efficient source of some of the most recent *technological advances* such as the laser and electron beams. Truly[6] electricity provides *humanity* with the energy of the future.

Notes to the Text

1. **transmission shafts, gear wheels, belts and pulleys** — *трансмісійні вали, зубчасті колеса, ремені і блоки*
2. **time and labour saving appliances** — *електроприлади, що економлять час і працю*
3. **induction motors** — *асинхронні електродвигуни*
4. **per capita** — *на людину; на душу населення*
5. **by-products** — *побічні продукти*
6. **truly** — *справді*

I. Read the sentences, translate them into Ukrainian and decide if they are true (T) of false (F).

1. Consumption of electricity is an indicator of the state of development and economic health of a nation.

2. With the appearance of the electrical motor, power cables appeared in the 19th century workshops.

3. The first industrial application of generators was in the silver workshops in New-York.

4. Electric lamp was invented by Volta.

5. The consumption of electricity doubles every twenty years.

6. One of the greatest advantages of electricity is that it is clean, easily regulated and generates by-products.

II. For the words given in A find the Ukrainian equivalents in B.

A	B
1. induction motor	1. прилад
2. consumption	2. повністю
3. development	3. асинхронний електродвигун
4.by-products	4. споживання
5. generator	5. розвиток
6. appliances	6. людство
7. advantage	7. генератор
8. humanity	8. побічний продукт
9. completely	9. перевага

III. Translate into English:

1. Неможливо уявити сучасну цивілізацію без електрики.

2. Електричну лампочку винайшов Томас Едісон.

3. Споживання електрики подвоюється кожні десять років.

4. Електрика забезпечує людство енергією майбутнього.

UNIT 3.

Text 1. KINDS OF ELECTRIC CURRENT

There are different kinds of electric current. The letters **a.c.** stand for *alternating current*. This current flows first in one direction and then in the opposite one. It usually has a frequency of 50 cycles.

The alternating current is very convenient for long-distance transmission. Although there are numerous cases when **d.c.** is required, at least 90 per cent of electrical energy to be generated at present is a.c. It finds wide application for lighting, heating, and industrial purposes.

I. Translate into Ukrainian:

conductor, field, direct current, lighting, voltage, frequency, cycle, transmission, direction, to generate.

II. Form sentences combining suitable parts of the sentences given in columns I and II.

I	II
1. The electric current is	1. electricity at rest.
2. Alternating current	2. the flow of electrons in one direction
3. Static electricity is	3. flows first in one direction and then in the opposite one.
4. Kinetic energy is	4. the energy of motion
5. The direct current is	5. the flow of electrons.

III. Translate into Ukrainian:

1. The unit of measure for frequency is one cycle.
2. Batteries generate direct current.
3. We require an a.c. electric motor for our experiment.
4. Direct current can be produced by generator.
5. What is the voltage in this circuit?

Text 2. FROM THE HISTORY OF ELECTRICITY

There are two types of electricity, namely, electricity *at rest* or in a static condition and electricity *in motion*, that is, the electric current. Both of them are made up of *electric charges*, static charges are at rest, while electric current flows and does work. Thus, they differ in their ability to serve mankind as well as in their behaviour.

Let us first *turn our attention* to static electricity. For a long time it was the only electrical phenomenon to be observed by man. As previously mentioned at least 2,500 years ago, or so, the Greeks knew how to get electricity by *rubbing* substances.

However, the electricity to be obtained by rubbing objects cannot be used to light lamps, to boil water, to run electric trains, and so on. It is usually very high in voltage and difficult to control, besides it discharges in no time.

As early as 1753, Franklin made an important contribution to the science of electricity. He was the first to prove that unlike charges are produced due to rubbing dissimilar objects. To show that the charges are *unlike* and *opposite*, he decided to call the charge on the rubber — *negative* and that on the glass — *positive*.

Who does not know that the first man to get the electric current was Volta after whom the unit of electric "pressure", the volt, was named? His discovery developed out of *galvanic experiments* with the frog.

Galvani observed that the legs of a dead frog jumped as a result of an electric charge. He tried his experiment several times and every time he obtained the same result. He thought that electricity was generated within the leg itself.

Volta began to carry out similar experiments and soon found that the electric source was not within the frog's leg but was the result of the contact of both dissimilar metals used during his observations.

However, to carry on such experiments was not an easy thing to do. He spent the next few years trying to invent a source of continuous current. To increase the effect obtained with one pair of metals, Volta increased the number of these pairs.

Thus the voltaic pile consisted of a copper layer and a layer of zinc placed one above another with a layer of flannel moistened in salt water between them. A wire was connected to the first disc of copper and to the last disc of zinc. The year 1800 is a date to be remembered: for the first time in the world's history a *continuous current* was generated.

Volta's Short Biography. Volta was born in Como, Italy, on February 18, 1745. For some years he was a teacher of physics in his home town. Later on, he became a professor of natural sciences at the University of Pavia.

After his famous discovery he travelled in many countries, among them France, Germany and England. He was invited to Paris to deliver lectures on the newly discovered "*Chemical source of continuous current*". In 1819 he returned to Como where he spent the rest of his life. Volta died at the age of 82.

I. Read the sentences, translate them into Ukrainian and decide if they are true (T) of false (F).

1. There are two types of electricity, namely, electricity at rest and electricity in motion.
2. Static charges flow and do work, while electric current is at rest.
3. At least 3,500 years ago, or so, the Romans knew how to get electricity by rubbing substances.
4. Franklin was the first to prove that unlike charges are produced due to rubbing dissimilar objects.
5. The first man to get the electric current was Galvani.
6. For the first time in the world's history a continuous current was generated in 1800.
7. Volta became a professor of natural sciences at the University of Paris.
8. In 1819 Volta returned to Como where he spent the rest of his life.
9. He was invited to New-York to deliver lectures on the newly discovered "Chemical source of continuous current".

II. For the words given in A find the Ukrainian equivalents in B.

A	B
1. electric current	1. спостерігати
2. discovery	2. розряджати
3. at rest	3. в русі
4. substance	4. мідь
5. discharge	5. відкриття
6. in motion	6. електричний струм
7. observe	7. речовина
8. layer	8. збільшувати
9. increase	9. в стані спокою
10. copper	10. шар
11. carry on	11. гальванічна батарея
12. voltaic pile	12. продовжувати

III. Translate into Ukrainian:

1. There are two types of electricity, namely, electricity in a static condition and electric current.

2. Long ago the Greeks knew how to get static electricity by rubbing substances.

3. The first man to get the electric current was Volta after whom the unit of electric pressure, the volt, was named.

4. Franklin decided to call the charge on the rubber – negative and that on the glass – positive.

5. For the first time in the world's history a continuous current was generated by Volta in 1800.

UNIT 4.

Text 1. *ELECTRIC CIRCUIT*

Electric circuit is a complete path along which the current flows from the source of supply to the load and then from the load back to the source.

The purpose of electrical source is to produce the necessary electromotive force required for the flow of current through the circuit

The current may pass through solid conductors, liquids, gases and vacuum. It may flow over transmission lines from the power-stations, through transformers, cables and switches, through lamps, motors and so on.

There are various kinds of electric circuits such as: open circuits, closed circuits, series circuits, parallel circuits and short circuits

I. For the words given in A find the Ukrainian equivalents in B.

A	B
1. power-station	1. вимикач
2. charge	2. електростанція
3. electromotive force	3. передача
4. transmission	4. джерело
5. series	5. послідовний
6. source	6. навантаження
7. flow	7. заряд
8. circuit	8. ЕРС
9. switch	9. протікати
10. load	10. коло

II. Answer the following questions.

1. What do we call an electric circuit?
2. What kinds of circuits do you know?
3. What do we require the electromotive force for?
4. What is the purpose of electrical source?
5. What substances may the electric current pass through?

Text 2. THE ELECTRIC CIRCUIT AND ITS ELEMENTS

The simplest *electric circuit* consists of a *source of energy* or *power source* (e.g., a primary cell, accumulator, or generator), a *receiver of energy* (e.g., an electric lamp, electric-heating device, or electric motor), and *two conductors* connecting the receiver and power source *terminals*.

The *power source* (or, for short, the source) transforms mechanical, chemical, thermal, or other energy into electromagnetic energy, which, for brevity, is often simply called electric energy. The *energy receiver* (or simply receiver), on the contrary, transforms the electric energy to other forms of energy: *radiant*, *thermal*, *mechanical* and so on.

The power source together with the conductors and receiver (load) connected to it form a *closed loop*, along which an uninterrupted stream of electric charge (an electric current) flows. This is called an electric circuit. With respect to the source, the conductors and receiver (load) form the so-called *external circuit*.

The direct cause of flow of electric current in a circuit is the ***electromotive force (e.m.f.)*** of the power source. Conventionally, the direction of the current in the circuit is taken to coincide with the direction of the e.m.f.

The *terminal* of the source through which the current «leaves» for the external circuit is called *positive* (+) and the terminal through which the current enters the source from the external circuit, the *negative* (–). The direction of the current is thus from + to – in the external circuit and from – to + inside the source.

Both the external circuit *and* the source possess ***resistance***, the value of which depends upon the *material*, *shape* and *dimensions of the conductors* composing these parts of the electric circuit.

The ***magnitude*** or the *intensity* of the current (or, simply, the current) in the circuit depends on the magnitude of the e.m.f. and the resistance of the whole circuit.

The relationship between these three quantities is expressed by ***Ohm's law***, which plays a very important role in electrical engineering, being the basis of many practical calculations.

According to this law, the current in the circuit is *directly proportional* to the e.m.f. and *inversely proportional* to the resistance R of the whole circuit:

$$I = \frac{E}{R}$$

Ohm's law can be applied to the circuit as a whole and separately to any portion of the circuit outside the power source.

VOCABULARY

1. **e. g. = for example** – *наприклад*
2. **for short** – *скорочено*
3. **with respect to** – *відносно*
4. **according to** – *відповідно до*
5. **to coincide** – *співпадати*
6. **so-called** – *так званий*
7. **both ... and** – *як ... так і; і ... і*
8. **as a whole** – *в цілому*

I. Translate into Ukrainian and write your own sentences using some of these words:

power source, terminals, receiver, electric circuit, external circuit, electromotive force, resistance, magnitude, relationship, quantities, electrical engineering, calculations, directly proportional, inversely proportional, separately, outside

I. Read the sentences, translate them into Ukrainian and decide if they are true (T) of false (F).

1. The simplest electric circuit consists of a power source, a receiver of energy and two conductors connecting the receiver and power source terminals.
2. The energy receiver transforms mechanical, chemical, thermal, or other energy into electric energy.
3. The direct cause of flow of electric current in a circuit is the electromotive force of the power source.
4. The direction of the current in the circuit does not coincide with the direction of the e.m.f.
5. The current in the circuit is inversely proportional to the e.m.f. and directly proportional to the resistance.

III. Translate into English.

1. Просте електричне коло складається з джерела енергії, споживача енергії та двох провідників, які з'єднують клеми джерела та споживача.

2. Споживач енергії перетворює електричну енергію на інші форми енергії: теплову, світлову, механічну тощо.

3. Безпосередня причина протікання електричного струму в колі – це електрорушійна сила джерела енергії.

4. Як зовнішнє коло, так і джерело мають опір, який залежить від певних факторів.

5. Величина струму залежить від ЕРС та опору всього електричного кола.

6. Відповідно до закону Ома, струм у колі прямо пропорційний до ЕРС і обернено пропорційний опору R усього кола.

IV. Answer the following questions:

1. What are the elements of the simplest electric circuit?

2. What elements form the so-called external circuit?

3. What is the direct cause of flow of electric current in a circuit?

4. a) What do we call the terminal of the source through which the current «leaves» for the external circuit? b) What do we call the terminal through which the current enters the source from the external circuit?

5. What is the direction of the current in the external circuit and inside the source?

6. What factors determine the resistance of the electrical circuit?

7. What depends on the magnitude of the e.m.f. and the resistance of the whole circuit?

8. State Ohm's law.

UNIT 5.

Text 1. *CONDUCTORS AND INSULATORS*

All substances can conduct electric current. Some substances, for example metals, conduct electric current easily. They are called *conductors*. Substances that offer great resistance to the flow of charges are called *insulators*. Rubber and glass are good insulators.

Conductivity or *conducting ability* depends on many factors.

Some of them are:

- ✓ the size of the wire used,
- ✓ its temperature,
- ✓ the kind of material to be used.

There is a great difference in the conducting ability of various substances. All metals are good conductors. But copper conducts the current more freely than iron, and silver is a better conductor than copper.

I. Find in the text English equivalents for:

протікання зарядів, чинити опір, залежати від багатьох факторів, провідність, ізолятор, здатність проводити.

II. Answer the following questions:

1. Can all substances conduct electric current easily?
2. What is a conductor?
3. What does conductivity depend upon?
4. What materials are the best conductors of electricity?
5. What insulators do you know?

III. Translate into English.

1. Мідь – гарний провідник електрики.
2. Провідність залежить від температури.
3. В колі повинна бути різниця потенціалів.
4. Що є одиницею вимірювання опору?
5. Срібло легко проводить електрику.

Text 2. CONDUCTORS AND INSULATORS

All substances have some ability of conducting electric current, however, they differ greatly in the ease with which the current can pass through them. Metals, for example, conduct electricity *with ease* while rubber does not allow it to flow freely. Thus, we have *conductors* and *insulators*.

What do the terms "conductors" and "insulators" mean? Substances through which electricity is easily transmitted are called conductors. Any material that strongly resists the electric current flow is known as an insulator.

Let us first turn our attention to *conductance*, that is, the conductor's ability of passing electric charges. The four factors conductance depends on are: the size of the wire used, its length and temperature as well as the kind of material to be employed.

It is not difficult to understand that a large water pipe can pass more water than a small one. In the same manner, a large conductor will carry the current more readily than a thinner one. The figure to the text illustrates this fact better than words alone.

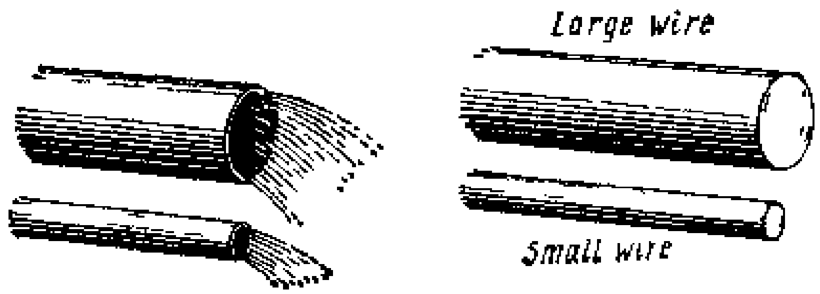


Fig. Compare water flow and current flow

It is quite understandable, too, that to flow through a short conductor is certainly easier for the current than through a long one *in spite of* their being made of similar material. Hence, the longer the wire, the greater is its opposition, that is resistance, to the passage of current.

As mentioned above, there is a great difference in the conducting ability of various substances. For example, almost all metals are good electric current conductors. Nevertheless, copper carries the current more freely than iron; and silver, *in its turn*, is a better conductor than copper.

Generally speaking, copper is the most widely used conductor. That is why the electrically operated devices in your home are connected to the wall socket by copper wires.

Indeed, if you are reading this book by an electric lamp light and somebody pulls the metal wire out of the socket, the light will go out at once. The electricity has not been turned off but it has no path to travel from the socket to your electric lamp.

The flowing electrons cannot travel through space and get into an electrically operated device when the circuit is broken. If we use a piece of string instead of a metal wire, we shall also find that the current stops flowing.

A material like *string*, which *resists* the flow of the electric current, is called an insulator. There are many kinds of insulation used to cover the wires. The kind used depends upon the purposes the wire or cord is meant for. The insulating materials we generally use to cover the wires are rubber, asbestos, glass, plastics and others.

Rubber covered with cotton, or rubber alone is the insulating material usually used to cover desk lamp cords and radio cords. Glass is the insulator to be often seen on the *poles* that carry the wires in city streets. Glass insulator strings are usually suspended from the towers of high voltage transmission lines.

One of the most important insulators of all, however, is air. That is why *power transmission line* wires are bare wires depending on air to keep the current from leaking off.

Conducting materials are by no means *the only* materials to play an important part in electrical engineering. There must certainly be a conductor that is a path, along which electricity is to travel and there must be insulators keeping it from leaking off the conductor.

I. Read the sentences, translate them into Ukrainian and decide if they are true (T) of false (F).

1. All substances can conduct electric current.

2. Metals does not allow current to flow freely, so they are insulators.

3. Substances through which electricity is easily transmitted are called conductors.

4. To flow through a short conductor is certainly more difficult for the current than through a long one in spite of they are made of similar material.

5. Any material that strongly resists the electric current flow is known as a conductor.

6. The flowing electrons can travel through space and get into an electrically operated device when the circuit is open or broken.

I. Answer the following questions.

1. What is discussed in the present article?

2. Do all substances conduct the electric current easily?

3. What is a conductor?

4. What does conductance depend upon?

5. What materials are the best conductors of electricity?

6. Does temperature influence the conductor’s resistance?

7. What feature of the conductor is illustrated in the figure to the text?

8. What is the difference between a conductor and an insulator?

9. What insulators do you know?

10. Why are power transmission line wires bare?

11. What insulation is used on the cords of your electrical devices?

12. Can we do without insulators?

13. What insulating materials do we generally use to cover the wires?

UNIT 6.

Text 1.

GENERATORS (I)

The dynamo was invented by Faraday in 1831. Modern generators and alternators still use the principle invented by the great English scientist.

The dynamo machines are used for production of the electric current. They transform mechanical energy into electrical energy. They produce about 90 per cent of all electric power. They are used to light up millions of lamps, to run trains and to drive the machines. Batteries could not supply enough electricity to do all this work.

There are two types of dynamos, namely, the generator and the alternator. The generator supplies d.c., which is similar to the current produced by a battery and the alternator, provides a.c.

In order to generate electricity, they must be provided with energy. This mechanical energy can be supplied by steam engines, steam or water turbines etc.

I. For the words given in A find the Ukrainian equivalents in B.

A	B
1. insulator	1. генератор змінного струму
2. path	2. постачати, подавати
3. to produce	3. приводити в рух
4. alternator	4. виробляти
5. circuit	5. провідність
6. power	6. ізолятор
7. to supply	7. шлях
8. to drive	8. електричне коло
9. charge	9. енергія
10. conductivity	10. заряд

II. Form sentences combining suitable parts of the sentences given in columns I and II.

I	II
1. The generator	1. transforms heat into work.
2. The electric circuit	2. transforms mechanical energy into electrical energy.
3. The alternator	3. supplies a. c.
4. The electric motor	4. is a path along which the current flows.
5. Steam engine	5. is a device which transforms mechanical energy into electrical one.

Text 2. GENERATORS

The dynamo invented by Faraday in 1831 is certainly a primitive apparatus compared with the powerful, highly efficient generators and alternators that are in use today.

Nevertheless, these machines operate on the same principle as the one invented by the great English scientist. When asked what use his new invention had, Faraday asked in his turn: "What is the use of a new-born child?" In fact, "the new-born child" soon became an irreplaceable device we cannot do without.

Although used to operate certain devices requiring small currents for their operation, batteries and cells are unlikely to supply light, heat and power on a large scale. Indeed, we need electricity to light up millions of lamps, to run trains, to lift things, and to drive the machines. Batteries could not supply electricity enough to do all this work.

That electric machines are used for this purpose is a well-known fact. Mechanical energy is turned directly into electrical energy with a loss of only a few percent by means of these machines. It is calculated that they produce more than 90 per cent of the entire world's electric power.

There are two types of dynamos, namely, the *generator* and the *alternator*. The former supplies d.c. which is similar to the current from a battery and the latter, as its name implies, provides a.c.

To generate electricity both of them must be continuously provided with energy from some outside source of mechanical energy such as steam engines, steam turbines or water turbines, for example.

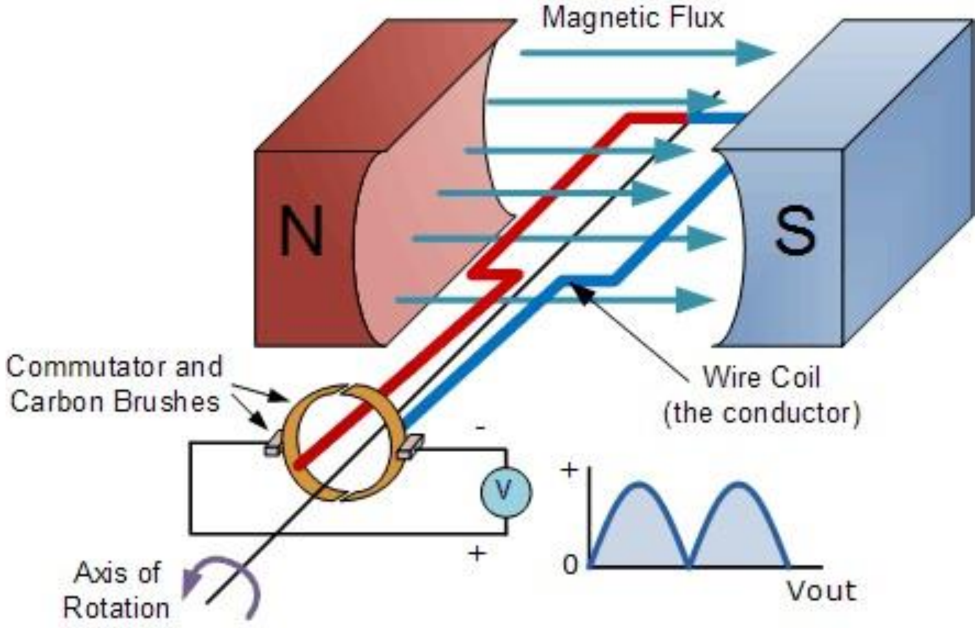


Fig. *A simple type of elementary direct current generator (dynamo)*

Both generators and alternators consist of the following principal parts: an ***armature*** and an ***electromagnet***. The electromagnet of a d.c. generator is usually called a stator for it is in a static condition while the armature (the rotor) is rotating.

Figure to the text shows the principles the construction of an elementary d.c. generator is based upon. We see the *armature*, the *electromagnet*, the *shunt winding*, the *commutator* and the *load*.

Alternators may be divided into two types:

1. alternators that have a stationary armature and a rotating electromagnet;

2. alternators whose armature serves as a rotor, but this is seldom done.

In order to get a strong e.m.f., the rotors in large machines rotate at a speed of thousands of revolutions per minute (r.p.m.). The faster they rotate, the greater the output voltage the machine will produce.

In order to produce electricity under the most economical conditions, the generators must be as large as possible. In addition to it, they should be kept as fully loaded as possible all the time.

I. Read the sentences, translate them into Ukrainian and decide if they are true (T) of false (F).

1. The dynamo was invented by Faraday in 1931.

2. Batteries and cells supply light, heat and power on a large scale.

3. Mechanical energy is turned directly into electrical energy with a loss of only a few percent by means of generators.

4. Alternator supplies d.c. which is similar to the current from a battery and the generator, as its name implies, provides a.c.

5. Both generators and alternators consist of the following principal parts: an armature and an electromagnet.

6. The slower the armature rotates, the greater the output voltage the machine will produce.

I. Find in the text English equivalents for:

генератор постійного струму, генератор змінного струму, незамінний пристрій, втрати, паровий двигун, водяна турбіна, якір, обмотка, колектор, електрорушійна сила, оберт за хвилину, вихідна напруга.

II. Answer the following questions.

1. When did Faraday invent the dynamo?
2. Was Faraday an American scientist?
3. Can batteries supply power on a large scale?
4. What do we need electricity for?
5. What are dynamo electric machines used for?
6. What types of dynamos do you know?
7. What are the principal parts of a generator?
8. In what condition is the stator of an electromagnet?
9. What does figure to the text show?

UNIT 7.

Text 1. GENERATORS (II).

The generators and alternators consist of the following principal parts: an *armature* and an *electromagnet*. The electromagnet of a d.c. generators is called a *stator* and the armature is called a *rotor*.

Alternators may be divided into two types:

1. alternators that have a stationary armature and a rotating electromagnet;
2. alternators whose armature serves as a rotor.

In order to get a strong e.m.f. the rotors in large machines rotate at a speed of thousands revolutions per minute (r.p.m.). The faster they rotate, the greater the output voltage the machine will produce.

In order to produce electricity under most economical conditions, the generators must be as large as possible. For example, the Dnipro hydroelectric power plant is equipped with 225,000 kW generators. Our industry produces even greater power installations of 1,200 MW for thermal power plants.

I. Find in text English equivalents for:

якір, електромагніт, статор, ротор, обертовий електромагніт, для того щоб, обертатись зі швидкістю, оберти на хвилину, вихідна напруга, генератор змінного струму, обладнаний, установка, теплоелектростанція, гідроелектростанція

II. Answer the following questions:

1. What types of generators do you know?
2. What are the principal parts of a generator?
3. What two types of alternators do you know?
4. What does the output voltage of a generator depend upon?
5. What generators is the Dnipro power station equipped with?

III. Make up as many sentences as yon can using the following words:

generator,	to transform,	electrical charges,	direct current,
conductor,	electric motor,	to produce,	to supply,
silver,	to flow,		circuit

Text 2. MAGNETOHYDRODYNAMIC GENERATOR

Magnetohydrodynamics (MHD) is a field of fluid mechanics. The latter deals with the flow of the fluid or gas conducting electricity in the magnetic field. As gases can flow too they are considered as liquids.

Faraday performed the first experiment in MHD in the early nineteenth century. He put two electrodes in the Thames River trying to develop an electrical signal from the flow of the river through the earth's magnetic field. There were two problems in this simple experiment.

The first one was the lack of combination of *electrical conductivity*, *velocity* and the *magnetic field*. The second problem was connected with the difficulties in the extraction of the electric current at the electrodes. The latter still remains a critical problem for the scientists to solve.

More than a hundred years ago in 1831, Faraday discovered ***electromagnetic induction***. Today every schoolchild knows the experiment from the school physics laboratory.

If a conductor connected to an electric circuit crosses the space between the poles of a magnet an electric current is induced in it. But the metal conductor can be replaced by any other conductor. For example, it may be a flow of electro conducting liquid or gas.

If gases are heated to some thousands of degrees the atoms that make them up are broken down into electrically charged particles, the latter interacting with the magnetic field. A high temperature gas in an MHD generator gives the same result as a copper *armature* in a conventional d.c. generator.

By means of suitable electrodes part of the energy of the ionized gas passing through the magnetic field is converted directly into electricity. *It is* this conversion *that* we are mostly interested in.

An MHD generator combines the functions of both a steam turbine and an electrical generator. As the energy of the gas is converted directly into electrical energy, an MHD generator is in principle a much simpler device than a turbogenerator.

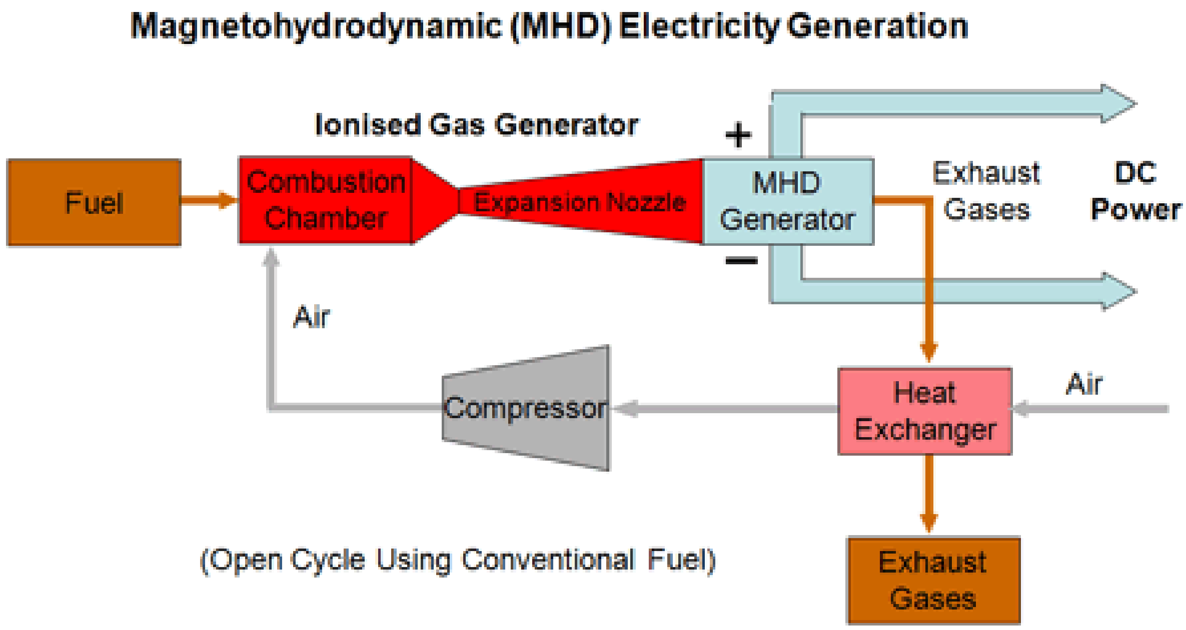


Fig. MHD generator

As shown in the figure to the text it consists of a nozzle, a channel with electrodes and insulators, located in the magnetic field. The generator *under consideration* has no moving parts that cause energy losses. Thus, it can *withstand* much higher temperatures than those of the turbines.

Because of high temperature operation a power plant with an MHD generator is more efficient than a turbine power plant.

Studies show that an MHD power plant can reach 50% efficiency, and 55-60% in the future, the highest obtainable *efficiency* of a thermal power plant is 40%.

MHD energy conversion becomes possible only with the right combination of gas velocity, electrical conductivity and magnetic field induction.

It is the study of the above-mentioned combination that has led to the development of ***three approaches to the MHD power generation***. The first one is the *open cycle generator* where the ionized gas flux is injected into the nozzle of the channel.

The second approach is the *closed cycle generator* in which plasma circulates inside the MHD generator itself. In the third, a liquid metal is used instead of plasma in the channel. All three approaches are investigated at present. So far, the open cycle generator seems to be the most *feasible* of them.

The first practical MHD power research was conducted in 1938 in the U.S. by Westinghouse in its Pittsburgh, Pennsylvania laboratories, headed by Hungarian Bela Karlovitz. In the 1960s, AVCO Everett Aeronautical Research began a series of experiments, ending with the Mk. V generator of 1965. It generated 35 MW, but used about 8 MW *to drive its magnet.*

By the end of the present century the *consumption* of electricity is expected to be ten times as great as it is today. To increase power production rapidly we shall not only have to build giant thermal power plants but also to develop principally new power generation methods. There is every reason to believe that large MHD stations will be operating in our country in the near future.

I. Read the sentences, translate them into Ukrainian and decide if they are true (T) of false (F).

1. Magnetohydrodynamics (MHD) is a field of fluid chemistry.

2. If a conductor connected to an electric circuit crosses the space between the poles of a magnet an electric current is induced in it.

3. An MHD generator combines the functions of both a steam turbine and an electrical generator.

4. A power plant with an MHD generator is less efficient than a hydropower plant.

5. The open cycle generator seems to be the most realistic.

II. Answer the following questions.

1. What does fluid mechanics deal with?
2. Why are gases considered as liquids?
3. Who discovered electromagnetic induction?
4. What experiment does every schoolchild know?
5. When do the atoms of gases break down into electrically charged particles?
6. What particles interact with the magnetic field?
7. What functions does an MHD generator combine?
8. Why is an MHD generator a much simpler device than the turbogenerator?
9. What does an MHD generator consist of?
10. Why is a power plant with an MHD generator more efficient than a turbine power plant?
11. What is the first approach to MHD power generation?
12. What can you say about the first MHD installation?
13. What is its capacity?

III. Point out which of the sentences contain the information from the text.

1. MHD energy conversion becomes possible only with the right combination of gas velocity, electrical conductivity and magnetic field induction.
2. A power plant with MHD generator is more efficient than a turbine power plant.
3. The problem of the extraction of the electric current at electrodes is important for MHD.
4. An MHD generator combines the functions of both a steam turbine and an electrical generator.
5. A high temperature gas in an MHD generator gives the same result as a copper armature in a conventional d.c. generator.

UNIT 8

Text 1. TRANSFORMERS

The transformer is a device for changing the electric current from one voltage to another. It is used in order to increase or decrease the voltage.

A simple transformer is a kind of induction coil. The principal parts of a transformer are two windings, that is coils, and an iron core.

The core which is supplied with the current is called the primary winding. The winding from which the current is taken is called the secondary winding.

The primary winding is connected to the source of supply and the secondary winding is connected to the load. The primary alternating current produces an alternating magnetic flux, and this flux passes through the turns of the secondary winding.

If the number of turns in the secondary winding is greater than the number of turns in the primary, the output voltage is larger than the input voltage and the transformer is called step-up transformer; if the primary has more turns than the secondary, the transformer is a step-down transformer.

I. Find in the text English equivalents for:

збільшити напругу, понизити напругу, первинна обмотка, вторинна обмотка, джерело живлення, індукційна котушка, кількість витків, магнітний потік, вхідна напруга, вихідна напруга, підвищувальний трансформатор.

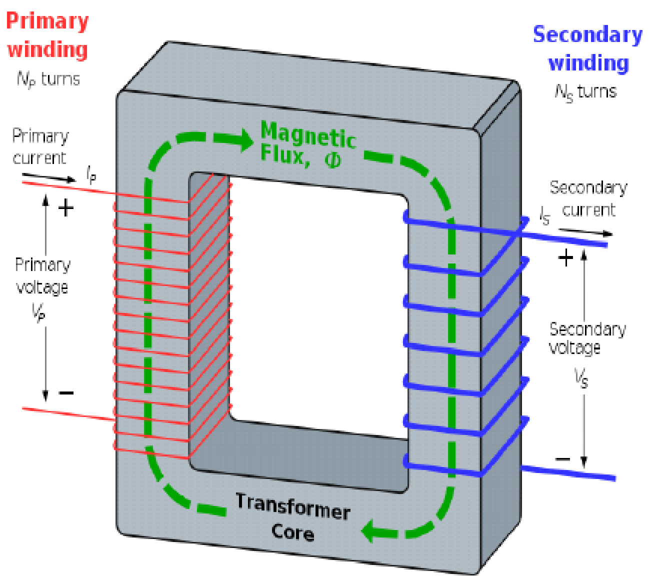
II. Answer the following questions:

1. What is a transformer?
2. What is a transformer used for?
3. What are the principal parts of a transformer?
4. What is the difference between primary and secondary winding?
5. What types of transformers do you know?

Text 2. ***TRANSFORMERS***

The *transformer* is a device for changing the electric current from one voltage to another. Actually, it is used for *increasing* or *decreasing* voltage.

A simple transformer is a kind of *induction coil*. It is well known that in its usual form it has no moving parts. On the whole, it requires very little maintenance provided it is not misused and is not damaged by lightning.



We may say that the principal parts of a transformer are *two windings*, that is coils, and an *iron core*. They call the coil which is supplied with current the *"primary winding"*, or just *"primary"*, for short.

The winding from which they take the current is referred to as the *"secondary winding"* or *"secondary"*, for short. The former is connected to the source of supply and the latter is connected to the load.

When the number of turns of wire on the secondary is *the same* as the number on the primary, the secondary voltage is the same as the primary, and we get what is called a "one-to-one" transformer.

In case, however, the number of turns on the secondary winding is greater than those on the primary, the *output voltage* is larger than the *input voltage* and the transformer is called a *step-up transformer*. On the other hand, the secondary turns being fewer in number than the primary, the transformer is known as a *step-down transformer*.

The transformer operates equally well to increase the voltage and to reduce it. By the way, the above process needs a negligible quantity of power. It is important to point out that device under consideration will not work on d.c. but it is rather often employed in direct-current circuits.

I. Read the sentences, translate them into Ukrainian and decide if they are true (T) of false (F).

1. The transformer is a device for changing the electric current from one resistance to another.

2. A simple transformer is a kind of iron core.

3. The principal parts of a transformer are two windings and an iron core.

4. The transformer operates equally well to increase the voltage and to reduce it.

5. The transformer will work on d.c. and it is rather often employed in direct-current circuits.

II. Form sentences combining suitable parts of the sentences given in columns I and II.

I	II
1. A "one-to-one" transformer is	a device for changing the electric current from one voltage to another.
2. The transformer is	the winding which is supplied with current.
3. Primary winding is	a device where the output voltage is larger than the input voltage.
4. Step-up transformer is	the winding from which they take the current.
5. Secondary winding is	a device where the secondary turns are fewer in number than the primary.
6. Step-down transformer is	a device where the secondary voltage is the same as the primary.

Text 3. ***TRANSFORMERS***

The transformer is a device that *steps-up* and *steps-down* alternating currents and voltages.

The essential parts of a transformer are: a *laminated iron core* upon which two separate *insulated coils* are wound – the *primary* and the *secondary*.

In most cases, the primary coil is connected to the *supply* or *main side* of the line where the alternating current sets up an *alternating magnetic flux*. This not only sets up a *counter voltage* equal and opposite in the primary coil, but also sets up a voltage in the secondary coil.

The *ratio* of the voltage in the secondary coil as compared to that in the primary coil depends upon the *amount* of magnetic flux, the *frequency* of the alternating current, and mainly the *number of turns* in the coils.

The only current that flows in the primary coil or windings is the *magnetizing current* to set up the flux in a closed, magnetic circuit and is usually a very small percentage of full load primary current of the transformer.

In a well-designed transformer, there is very little magnetic leakage. The effect of the leakage is to cause a decrease of secondary voltage when the transformer is *loaded*.

When a current flows through the secondary *in phase* with the secondary voltage a corresponding current flows through the primary in addition to the magnetizing current previously mentioned. The *magnetizing effects* of the two currents are *equal* and *opposite*.

I. Find in the text English equivalents for:

підвищення, ізольовані котушки, пониження, магнітний потік, вторинна котушка, частота, число витків, первинна котушка, магнітні втрати, зменшення, під навантаженням.

II. Read the sentences, translate them into Ukrainian and decide if they are true (T) of false (F).

1. The transformer is a device that steps-up and steps-down direct currents and voltages.

2. The essential part of a transformer is a laminated iron core.

3. The primary coil is connected to the supply or main side of the line where the alternating current sets up an alternating magnetic flux.

4. The ratio of the voltage in the secondary coil as compared to that in the primary coil depends upon the amount of magnetic flux.

5. In a well-designed transformer, there is a lot of magnetic leakage.

6. The magnetizing effects of the two currents are equal and opposite.

III. Answer the following questions:

1. Is a transformer a device that steps-up and steps-down direct currents and voltages?

2. How many coils are there in a transformer? How do we call them?

3. The ratio of the voltage in the secondary coil as compared to that in the primary coil depends upon the amount of magnetic flux, the frequency of the alternating current, and mainly the number of turns in the coils, doesn't it?

4. What is the only current that flows in the primary coil or winding?

5. Is there any magnetic leakage in a well-designed transformer?

IV. Be ready to discuss the following questions in pairs:

1. What is a transformer? What are its essential parts? How do they function?

2. How do we get a step-up, step-down and one-to-one transformer?

3. A transformer will not work on d.c. but it is rather often employed in direct-current circuits, is it?

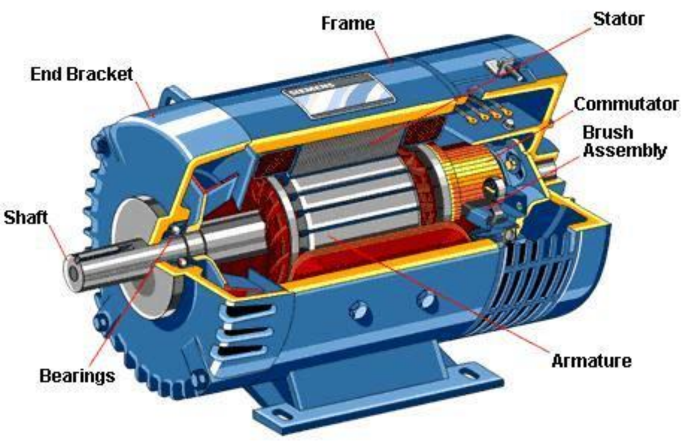
UNIT 9.

Text 1. ELECTRIC MOTOR

We know that generator transforms *mechanical energy* into *electric energy*. The function of an electric motor is just *the reverse*, that is, it transforms electric energy into mechanical energy. Electric motors are known to turn machinery and various *appliances*.

There is a wide variety of d.c. and a.c. motors. There are *shunt motors*, *series motors*, *synchronous motors*, *induction motors*, single-, two-, and three-phase motors.

Direct current motors are of three principal kinds. They are named *according to* the manner in which their field coils are connected to the *armature*. They are named respectively: *series*, *shunt* and *compound*.



A.c. motors may be divided into two kinds:

I. *synchronous*;

II. *asynchronous* or induction motors.

There is certainly some difference between electric motors and generators but in both of them we find an *armature* with *windings*, a *commutator* and *brushes* combined with *electromagnet* for producing the *magnetic field*.

I. Find in the text English equivalents for:

електричний двигун постійного струму, електричний двигун з послідовним збудженням, асинхронний двигун, однофазний двигун, синхронний двигун, двигун з паралельним збудженням, двигун змінного струму, двигун із змішаним збудженням.

II. For the words given in A find the Ukrainian equivalents in B.

A	B
1. turn	1. обмотка
2. brush	2. поле
3. coil	3. вхід
4. field	4. електричне коло
5. winding	5. виток
6. circuit	6. колектор
7. to supply	7. постачати, забезпечувати
8. armature	8. енергія, потужність
9. input	9. щітка
10. commutator	10. якір
11. output	11. вихід
12. power	12. котушка

III. Answer the following questions:

1. What is a motor used for?
2. What kinds of motors do you know?
3. What parts of a motor do you know?
4. Does electric motor transform mechanical energy into electrical energy?

Text 2.

ELECTRIC MOTOR

The electric motor is a *device* used to transform *electrical energy* into *mechanical energy*. We know it to turn machinery and various *appliances*.

We have already seen the generator convert mechanical energy into electric energy. Now, the process is *reversed*. It is electricity that is supplied to the machine and it is motion that we obtain.

From all that has been said in the previous articles about our getting magnetism from electricity and about the generation of electric current by using magnetism, it is *obvious* that generators and motors are similar *in certain respects*.

There is certainly some difference in detail but in both of them we find an *armature* with *windings*, a *commutator* and *brushes* combined with an *electromagnet* for producing the *magnetic field*.

However, in an electric motor, one *shunt winding* is not sufficient and a second one called *a series winding* should be added. "Why is it necessary?" one might ask. The fact is that the motor should have a powerful effect at the very moment when the current is switched on, as for instance, in an electric tram or a train. A very strong magnetic field is needed to obtain a so-called powerful *starting torque*. This is achieved by adding a series winding to the *magnetic coils*.

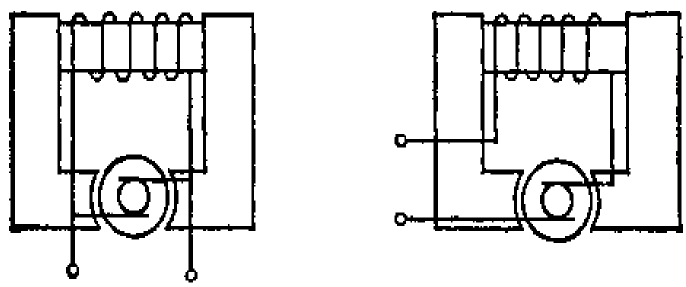


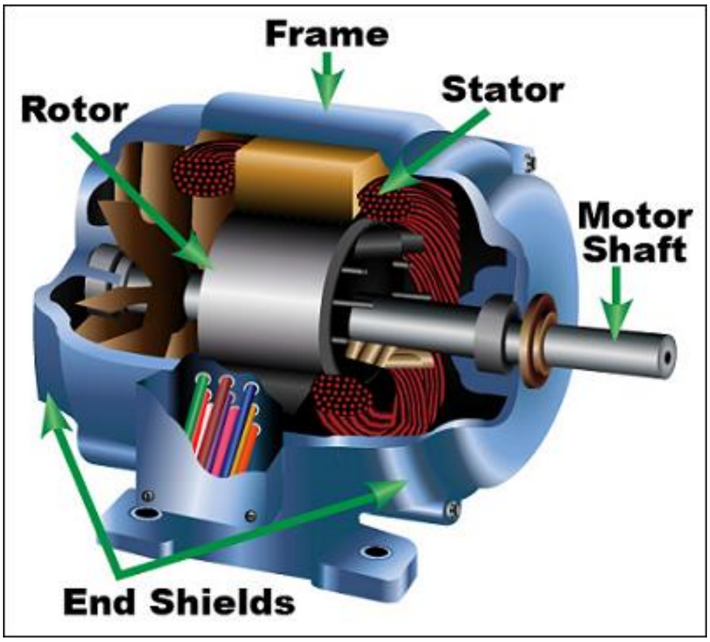
Fig. Shunt and series windings of armature and field coils

It is connected not in shunt with the armature but in series with it. Thus, all the *heavy starting current*, passing through the *armature winding*, now passes through the *series field coil* and provides a strong field necessary for starting, the *shunt field winding* providing the running conditions.

No appliance ever created by man has probably such a wide range of sizes and such a variety of application as a motor. In fact, on the one hand, there are all kinds of mighty giants in the motor world.

These giants are known to perform *innumerable* operations wherever required. On the other hand, there exist all kinds of small-sized and even *minute motors* which are able to power various *complex machines* and operate equally well *under any conditions*.

Up to now, nothing was said of what a motor does in our homes. In a modern home there are many different electric motors in machines and devices *utilized* to meet our daily *requirements*: to tell the time, to wash clothes, to cool the refrigerator, to clean or brush various things, to shave, to circulate air in a warm room on a hot summer day and so on.



In fact, vacuum cleaners, washing machines, and modern refrigerators do work *thanks to* electric motors. It follows that in the electric motor we have a valuable and powerful appliance capable of *fulfilling* the required operations exactly and with just the desirable power and rate of motion. It is readily switched on, at will, and it continues running until we switch it off.

There are often cases when it is simply impossible to replace it by any other means. In short, the motor finds application in industry and engineering, in agriculture and transport, in medicine and our homes.

I. Answer the following questions.

1. What device is discussed in the present article?
2. What is a motor employed for?
3. What kind of motors do you know?
4. Does the generator convert electrical energy into mechanical energy?
5. What parts of a motor do you know?
6. What is a very strong magnetic field needed for?
7. What does the shunt field winding provide?
8. What does a motor do in our homes?
9. Do motors serve you every day?
10. Where does a motor find its wide application?

II. Find in the text Ukrainian equivalents for:

to turn machinery, to convert mechanical energy into electric energy, in certain respects, an armature with windings, a commutator and brushes, a shunt winding, a series winding, starting torque, a wide range of sizes, to perform innumerable operations, to power various complex machines, to meet our daily requirements, thanks to electric motors, find application, desirable power, rate of motion.

III. Read the sentences, translate them into Ukrainian and decide if they are true (T) of false (F).

1. The electric motor is a device used to transform mechanical energy into electrical energy.

2. Generator converts mechanical energy into electric energy.

3. Generators and motors are similar in certain respects.

4. In generators and motors we find an armature with windings, a commutator and brushes combined with an electromagnet for producing magnetic field.

5. In an electric motor, one shunt winding is quite sufficient.

6. A very strong magnetic field is needed to obtain powerful starting torque.

7. There are no small-sized or minute motors, only all kinds of mighty giants in the motor world.

8. In a modern home there are many different electric motors in machines and devices.

9. Vacuum cleaners, washing machines, and modern refrigerators work thanks to amplifiers.

10. The motor finds application in industry and engineering, in agriculture and transport, in medicine and our homes.

IV. Be ready to speak about the role of electric motors in our homes and in industry.

UNIT 10.

Text 1.

POWER TRANSMISSION

Whenever the electric energy is produced at the thermal, hydro- or atomic power station, it is to be transmitted over wires to the substation and then to the consumer. However, the longer the wire, the greater is its resistance to current flow and the higher the resistance, the greater are the heating losses in electric wires.

These losses can be reduced in two ways. We can reduce resistance it is necessary to make use of a better conducting material and it is possible to reduce current in the transmission system by employing transformers.

It is known that high voltage means low current and low current reduces heat losses. For this reason, high-tension transmission lines are being built in Ukraine now.

I. Find in the text English equivalents for:

передавати по проводах, теплові втрати, зменшувати, опір, провідникові матеріали, високовольтні лінії електропередач, атомна електростанція, використання трансформаторів.

II. Read the sentences, translate them into Ukrainian and decide if they are true (T) of false (F).

1. The longer the wire, the greater is its resistance to current flow.
2. The higher the resistance, the smaller are the heating losses in electric wires.
3. The electric energy is produced at the thermal, hydro- or atomic power plants.
4. Power is transmitted over wires to the substation and then to the consumer.
5. We cannot reduce heating losses in electric wires.
6. High voltage means small heat losses.

III. For the words given in A find the Ukrainian equivalents in B.

A	B
1. charge	1. навантаження
2. circuit	2. течія, протікання
3. turn	3. провід
4. coil	4. джерело
5. stream	5. потік
6. winding	6. з’єднувати
7. power	7. ізолятор
8. to supply	8. заряд
9. load	9. обмотка
10. wire	10. енергія
11. insulator	11. постачати, забезпечувати
12. source	12. котушка
13. connect	13. передавати
14. to transmit	14. коло
15. flow	15. виток, обертати

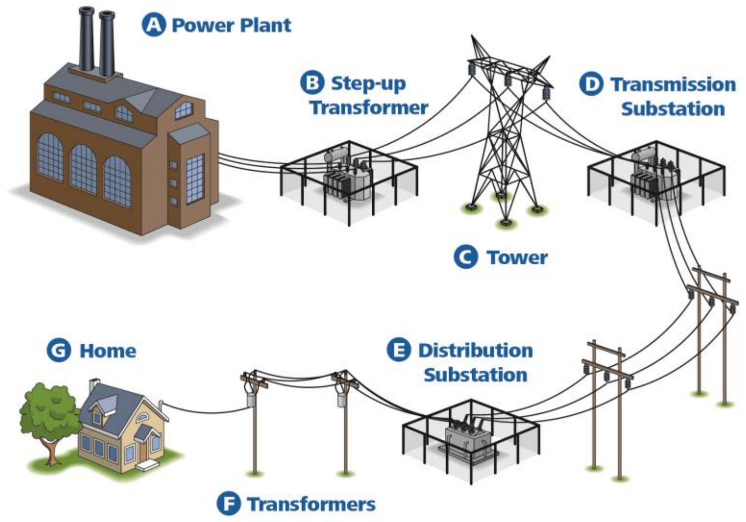
Text 2.

POWER TRANSMISSION

They say that about a hundred years ago, power was never carried far away from its *source*. Later on, the *range of transmission* was expanded to a few miles.

And now, in a comparatively short period of time, electrical engineering has achieved so much that it is quite possible, at will, to *convert* mechanical energy into electrical energy and *transmit* the latter over hundreds of kilometres and more in any direction required. Then in a suitable locality the electric energy can be *reconverted* into mechanical energy whenever it is desirable.

It is not difficult to understand that the above process has been made possible *owing to* generators, transformers and motors *as well as* to other necessary electrical equipment. In this connection *one cannot but mention* the growth of electric power generation in this country.



It goes without saying that *as soon as* the electric energy is produced at the power-station, it is to be transmitted over wires to the *substation* and then to the *consumer*. However, *the longer* the wire, *the greater* is its resistance to current flow.

On the other hand, the higher the offered resistance, the greater are the *heating losses* in electric wires. One can reduce these *undesirable losses* in two ways; namely, *one can* reduce *either* the resistance *or* the current.

It is easy for us to see how we can *reduce resistance*: it is necessary to make use of a better *conducting material* and *as thick* wires *as possible*. However, such wires are calculated to require too much material and, hence, they will be too expensive.

Can the current be reduced? Yes, it is quite possible to reduce the current in the *transmission system* by employing transformers. In fact, the *waste of useful energy* has been greatly decreased *due to* high-voltage lines.

It is well known that high voltage means low current, low current in its turn results in reduced *heating losses* in electrical wires. It is dangerous, however, to use power at very high voltages for *anything but* transmission and distribution. For that reason, the voltage is always reduced again before the power is made use of.

I. Find in the text English equivalents for:

діапазон передачі, теплові втрати, завдяки генераторам, небажані втрати, зменшити опір, зменшити струм, із застосуванням трансформаторів, втрати корисної енергії, завдяки високовольтним лініям електропередач

II. Read the sentences, translate them into Ukrainian and decide if they are true (T) of false (F).

1. Hundred years ago, power was never carried far away from its source.
2. Now it is not possible to convert mechanical energy into electrical energy and transmit the latter over hundreds of kilometres.
3. The longer the wire, the greater is its resistance to current flow.
4. The smaller the resistance, the smaller are the heating losses in electric wires.
5. One can reduce these undesirable heating losses only by reducing resistance.
6. It is necessary use of a better conducting material and as thick wires as possible.
7. It is impossible to reduce the current in the transmission system by employing transformers.
8. The waste of useful energy can be greatly decreased due to high-voltage lines.
9. It is dangerous to use power at very high voltages for anything but transmission and distribution.

III. Answer the following questions.

1. Is it possible, at will, to convert mechanical energy into electrical energy and transmit the latter over hundreds of kilometres and more in any direction required?
2. What electrical equipment do we use in the transmission systems?
3. What is the dependence between resistance, current and heating losses?
4. Is it possible to reduce the current in the transmission system by employing transformers?
5. High voltage means low current; low current in its turn results in reducing heating losses in electrical wires, doesn't it?
6. Why do we always reduce the voltage again before the power is made use of?
7. Where do we use high voltages and why?

Англо – український словник

A

ability – здатність

alternating current (a. c.) – змінний струм

alternator – генератор змінного струму

appliance – прилад

application – застосування

armature – якір

B

brush – щітка

C

cable – кабель

case – випадок

change – змінювати, перетворювати

charge – заряд, заряджати

circuit – коло, схема

coil – котушка, обмотка

commutator – колектор

compound motor – електродвигун із змішаним збудженням

condition – умова

conductivity – провідність

connect – з’єднувати

consumer – споживач

copper – мідь

core – осердя

current – струм

cycle – герц, цикл

D

decrease – зменшувати

device – прилад, пристрій

direct current (d. c.) – постійний струм

direction – напрям

drive – приводити в рух, привод

E

electricity – електрика

electromotive force (e. m. f.) – електрорушійна сила (ЕРС)

equip – оснащати, обладнувати,

equipment – обладнання

F

field – поле

field coils – обмотка збудження

flow – текти, протікати, потік

flux – потік

frequency – частота

G

generate – виготовляти

generator – генератор

glass – скло

H

heat – тепло

heating – нагрівання, обігрівання

high-tension – високовольтний

hydro- – гідро-

I

increase – збільшувати

induction – індукція

input – вхід

installation – установка

insulator – ізолятор

iron – залізо

J

К

L

lighting – освітлення

load – навантаження

losses – втрати

M

machinery – механізм

motion – рух

N

a number of – декілька, багато

O

offer – пропонувати

opposite – протилежний

output – вихід, (вихідна) потужність

P

path – шлях

phase – фаза

plant – станція, завод

power – енергія, потужність

power station – електрична станція

primary – первинний

produce – виготовляти

provide – забезпечувати

purpose – ціль

Q

R

reduce – зменшувати

resistance – опір

rest – спокій, в стані спокою

reverse – зворотній, змінювати напрям на зворотній

revolution – оберт

rotate – обертати

rubber – гума, каучук

rubbing – тертя

S

secondary – вторинний

series – послідовний

series motor – двигун з послідовним збудженням

short circuit – коротке замикання

shunt motor – двигун з паралельним збудженням

silver – срібло

single- – одно-

source – джерело

stationary – стаціонарний

steam engine – паровий двигун

step down – понижувати

step up – підвищувати

stream – потік

substance – речовина

supply – запас, постачати

switch – перемикати, перемикач

T

thermal – тепловий

transformer – трансформатор

transmission – передача

transmit – передавати

turbine – турбіна

turn – обертати, оберт

U

unit – одиниця

unit of measure – одиниця вимірювання

V

voltage – напруга

W

winding – обмотка

wire – провід, дріт

X

Y

Z

TEXTS FOR ADITIONAL READING

SIGNIFICANT EVENTS IN THE HISTORY OF ENERGY BY FUEL

WOOD (BIOMASS)

Pre-1885 Wood was the primary source for cooking, warmth, light, trains, and steamboats; cutting wood was time-consuming, hard work.

ELECTRICITY

1700s After eons of superstitious imaginations about electricity, Ben Franklin figured out that static electricity and lightning were the same; his correct understanding of the nature of electricity paved the way for the future.

1830-1839 Michael Faraday built an induction dynamo based on principles of electromagnetism, induction, generation, and transmission.

1860s Mathematical theory of electromagnetic fields was published; Maxwell created a new era of physics when he unified magnetism, electricity, and light; one of the most significant events, possibly the very most significant event, of the nineteenth century was Maxwells discovery of the four laws of electrodynamics ("Maxwells Equations"), which led to electric power, radios, and television.

COAL

1763-1774 Pumping water from coal mines was a most difficult and expensive problem; the steam engine developed by James Watt during these years provided the solution; Watt's steam engine remained basically unchanged for the next century, and its uses expanded to change the whole nature of industry and transportation.

1885-1950 Coal was the most important fuel; one-half ton of coal produced as much energy as 2 tons of wood and at half the cost, but it was hard to stay clean in houses heated with coal.

Late 1860s The steel industry gave coal a big boost.

1982 Coal accounted for more than half of the supply of electricity, but little was used in homes; in terms of national electricity generation, hydropower, natural gas, and nuclear energy contributed between 10% and 15% each.

OIL

1870 Oil had become the country's second biggest export after Edwin Drake started the industry.

1890 Mass production of automobiles began, creating demand for gasoline; prior to this, kerosene used for lighting had been the main oil product.

1951-present Oil has given us most of our energy; automobiles increased the demand for oil.

1960 The Organization of Petroleum Exporting Countries (OPEC) was formed by Iran, Iraq, Kuwait, Saudi Arabia, and Venezuela; the group has since grown to include 11 member countries.

1970 U.S. production of petroleum (crude oil and natural gas plant liquids) reached its highest level at 11.7 million barrels per day; production in the lower 48 states has been generally declining since 1970; some of this decline has been offset by increased Alaskan production after 1978.

1993 For the first time, the United States imported more oil and refined products from other countries than it produced. This trend continues today.

NUCLEAR

1906 Albert Einstein discovered the special theory of relativity which unified mass, energy, magnetism, electricity, and light with the equation $E = mc^2$

(energy = mass times the square of the speed of light); this led to nuclear medicine — and a much longer life span — astrophysics, and commercial nuclear electric power.

1942 Scientists produced nuclear energy in a sustained nuclear reaction.

1957 The first commercial nuclear power plant began operating.

1995 Nuclear power contributed about 20% of the nation's electricity.

ETHANOL

1826 Samuel Morey developed an engine that ran on ethanol and turpentine.

1860 German engine inventor Nicholas Otto used ethanol as the fuel in one of his engines; Otto is best known for his development of a modern internal combustion engine (the Otto Cycle) in 1876.

1917-1918 The need for fuel during World War I drove up the ethanol demand to 50-60 million gallons (189-227 million liters) per year.

1920s Gasoline became the motor fuel of choice; Standard Oil began adding ethanol to gasoline to increase octane and reduce engine knocking.

1930s Fuel ethanol gained a market in the Midwest; more than 2,000 gasoline stations in the Midwest sold gasohol, which was gasoline blended with between 6% and 12% ethanol.

1945-1978 Once World War II ended, with reduced need for war materials and with the low price of fuel, ethanol use as a fuel was drastically reduced; from the late 1940s until the late 1970s, virtually no commercial fuel ethanol was available anywhere in the United States.

1975 The United States begins to phase out lead in gasoline; ethanol becomes more attractive as a possible octane booster for gasoline; the Environmental Protection Agency (EPA) issued the initial regulations requiring reduced levels of lead in gasoline in early 1973; by 1986, no lead was to be allowed in motor gasoline.

1979 Marketing of commercial alcohol-blended fuels began; Amoco Oil Company began marketing commercial alcohol-blended fuels, followed by Ashland, Chevron, Beacon, and Texaco.

1979 Congress enacted a series of tax benefits to ethanol producers and blenders; these benefits encouraged the growth of ethanol production.

1988 Ethanol was first used as an oxygenate in gasoline; Denver, Colorado, mandated oxygenated fuels (fuels containing oxygen) for winter use to control carbon monoxide emissions.

1992 The Energy Policy Act of 1992 (EPACT) provided for two additional gasoline blends — 7.7% and 5.7% ethanol, respectively.

GEOTHERMAL

1900s Conversion of high-grade hydrothermal resources to electricity began in Italy.

1960 The first commercial-scale development tools were placed in California at The Geysers, a 10-megawatt unit owned by Pacific Gas & Electric.

1972 Deep well drilling technology improvements led to deeper reservoir drilling and access to more resources.

1977 Hot dry rock was demonstrated in 1977; scientists developed the first hot dry rock reservoir at Fenton Hill, New Mexico.

1978 U.S. Department of Energy (DOE) funding for geothermal research and development was $106.2 million in fiscal year 1978, marking the first time the funding level surpassed $100 million; it remained at more than $100 million until fiscal year 1982, when it was reduced to $56.4 million.

1982 Geothermal electric generating capacity, primarily utility-owned, reached a new high level of 1,000 megawatts.

1988 U.S. Department of Energy and the Electric Power Research Institute operated a 1-megawatt geopressured power demonstration plant in Texas, extracting methane and heat from brine liquids.

1994 California Energy became the world's largest geothermal company through its acquisition of Magma Power; near-term international markets gained the interest of U.S. geothermal developers.

1995 During the period 1985-1995, U.S. geothermal developers had added nearly 1,000 megawatts of geothermal electric generating capacity outside The Geysers; worldwide geothermal capacity reached 6,000 megawatts.

Source: U.S. Department of Energy

THE HISTORY OF ENERGY

Beginning in ancient times, fire was discovered and put to work. This type of energy allowed primitive peoples to cook, heat their dwellings, and scare wild animals away. This chapter explores the history of the discovery and use of energy and the importance it played in the development of human civilization. It begins by looking at the historical development of different forms of energy and then examines the development of energy in the United States.

THE HISTORICAL DEVELOPMENT OF ENERGY

Humans have used fire for thousands of years — even as far back as the late Stone Age. Archaeologists have determined that cave dwellers kept their caves warm with fires that were kept continually burning. Later, humans used fire in more sophisticated ways, such as for cooking food, providing light, firing pottery, smelting **ore**, and making glass.

In ancient times, people used the energy stored in their own muscles to do work, such as hunting, gathering food, and building shelter. Simple tools were invented to assist in these efforts. The earliest tools were made of wood. Later, they were made from metal. Human power was also used to make the first boats and then to propel them by using poles and oars.

Some of the work was very difficult to do with just human power, so people turned to animals such as oxen. Animals supplied the energy necessary to complete several tasks: they provided transportation, helped move heavy goods from one place to another, and were used to plow fields for cultivation and pump water for irrigation. People have used animals to pull plows for thousands of years; the first plows can be traced back to Mesopotamia in 4000 B.C.

Wind Energy

Wind is another usable energy source that can be traced back thousands of years. The first mechanical device that was built to use the wind as a source of power was the sailboat. Sailboats and larger sailing ships provided a critical service because they allowed humans to begin exploring and trading with other civilizations. For this, harbors were built, creating towns and cities along coastlines around the world.

The first sailing ships had simple square sails that simply carried them in the direction the wind blew. It was Arab sailors who discovered how to sail into the wind using a triangular sail called the lateen — similar to the triangular sails that are still used today.

The first machine designed to use wind power to do work on land was the windmill, which was invented in the seventh century in Persia (now Iran). This new technology then spread to the Middle East and other countries such as India and China. The windmill was one of the first large-scale inventions designed to make peoples' workloads easier. Windmills were initially used to grind grain between heavy millstones to make flour. They were also used to pump water from rivers to irrigate crops. In sawmills, people used the motion of the shaft to run a saw, which slid up and down to slice rough logs into pieces of lumber.

Windmills were not built in Europe until the twelfth century. The Europeans used them to generate power and invented a new type of mill, called the post mill. A center post grounded this type of windmill, and the whole building turned around the center post so that the sails always faced into the wind. The stationary windmill — where only the top of the structure in which the sails were mounted turned into the wind — followed this.

Wind-powered grain mills and sawmills were replaced by more efficient machinery in the early 1900s. Some farmers still use windmills today, however, to pump water and drain flooded areas and to pull up underground water for irrigating crops. Today, high-powered windmills, called wind turbine generators, are used to make electricity.

Solar Energy

Solar energy has also been used since ancient times. The Greeks and Romans were among the first civilizations to use solar energy. They built their homes and other buildings facing south in order to take advantage of the Sun's strongest rays.

The American Indians also considered the sun when they built their dwellings. They built their structures of thick clay, which is able to absorb and hold heat from the Sun. People then learned to use the Sun to power machinery. Solar pumps and furnaces existed in the 1700s. By the 1800s, inventors were working with solar steam engines. Today, scientists continue to work with solar energy to find better ways of gathering and storing the sun's energy.

Fossil Fuels

It has been documented that the Chinese were using coal as early as 1000 B.C. to bake porcelain. The ancient Greeks also wrote about it in their history. In the Western countries, many of the forests had been destroyed by the 1100s to build houses and ships. Wood to heat houses became expensive, so people began looking for alternate ways to provide heat to their homes.

By the 1600s, coal had grown in popularity as a heating source. It was also used in breweries, glass-making, brick making, and many other businesses. Coal continued to grow in popularity. Originally, it was mined from shallow near-surface deposits. As this coal was used, miners began building mine shafts in order to go deeper into the ground where many coal deposits existed.

Coal mining was very hazardous. Shafts and tunnels had to be supported by beams. There was also the constant danger of cave-ins, explosions, or fires. By the beginning of the 1700s, coal was used in tall furnaces. This marked the beginning of the Industrial Revolution. England had many coal deposits, and during that time, it became a very wealthy nation because of this. With the invention of the steam engine, the demand for coal further increased. Coal is the energy source that significantly changed civilization and triggered the development of the modern world.

People have used petroleum since at least 3000 B.C. Mesopotamians used “rock oil” in architectural adhesives, ship caulks, medicines, and roads. Two thousand years ago, the Chinese refined crude oil for use in lamps and in heating homes.

In the past, petroleum was collected in small containers from where it oozed from the ground. In America, the Indians, doctors, and pharmacists used it as a form of medicine. For example, the Indians had used it for hundreds of years to treat skin sicknesses and breathing difficulties.

People then began to find other uses for petroleum. Eventually, it replaced whale oil for lighting, and the oil lamp was invented. Most experts credit Edwin L. Drake with starting the oil industry on a large scale. In 1858, the Seneca Oil Company, which was interested in oil as a fuel, hired Drake to drill a well near Titusville, Pennsylvania.

Drake worked with Billy Smith, a well digger, and dug one pit after another. The men used a wooden rig and a steam-run drill. Because each pit they dug was threatened with water and cave-ins, Drake ran an iron pipe deep into the ground and drilled from inside it. The pipe acted as a casing and kept Drake’s path clear for drilling. About a year later, Drake and Smith had dug a well 69.5 feet (21.2 meters) deep. On August 27, 1859, the oil suddenly swept up the shaft.

Gas as an energy source was first manufactured in the late eighteenth century. Scientists discovered that gas could be produced from heating coal without using air — because of this, the gas was called coal gas.

William Murdock, a British engineer, is known as the father of the gas industry. In 1792, he was using gas to light his own home. Coal gas was first used for public lighting with gas-lit street-lamps and public buildings. From there, its use spread to private homes.

In order to transport the gas, it was stored in elastic water skins that were stowed in horse-drawn wagons. A long tube fitted with a tap was put into the water skins. This controlled the dispensing of the gas. The wagon delivered the gas to individual homes by plugging the tube into the customer’s tank. The tap was then opened, and straps were tightened around the water skins to force the gas from the skin into the tank. Eventually, gas was stored in cylinders, making it less cumbersome to deliver.

Gas began to be used as a fuel in other modes of transportation, as well. Trains, steamboats, and ships carried gas in bottles. As the demand for gas increased, more efficient delivery methods were experimented with, and eventually pipes were placed underground to directly deliver the gas from factory to home. By this time, gas was not only used for lighting, but for cooking and heating, as well.

Electricity

In 1802, Sir Humphrey Davy, an Englishman, invented the first electric light. He experimented with passing an electric spark between two conductors stuck in a battery. He added a small charcoal rod at the end of each conductor. His apparatus was then enclosed in a glass globe.

For the next few decades, inventors used this invention to light entire cities. Other inventors dreamed of having the electric light available in every home. They encountered many problems, however, in making this work. The power of the bulb needed to be refined, and a feasible method of delivering the light to customers had to be developed.

The American inventor Thomas A. Edison solved these problems. Through experimentation, he refined the light-bulb. A very fine carbon wire controlled the bulb’s glow. His work was the model for the modern-day bulb. In 1882, Edison also developed one of the first electrical power plants that generated and distributed electricity. It made affordable electricity possible and had a profound effect on peoples’ lives.

People dreamed of building the ideal engine. A Belgian electrician — Zenobe Gramme — found the solution. He and his associate, Hippolyte Fontaine, invented a special steam machine that could run two generators.

A generator is a device that changes mechanical energy into electrical energy. These two inventors reasoned that if one generator quit working, the other could just replace it. But while one generator was producing electricity, the other was also in motion, working. They realized their machine was also reversible. It could change its own electrical energy into mechanical energy. This invention became the first electric motor.

The electric motor was first used as energy to power trains. It appeared in 1879 in Germany and then in England in 1887. In 1895, the electric train concept was brought to the United States.

Today, in most areas of the world, diversity and evolution of energy supplies has been the rule. In many areas, human labor, animal power, and biomass energy (wood) are still the primary sources of energy.

THOMAS EDISON

Thomas Edison was born in 1847 in Milan, Ohio. Even as a young boy, Edison had an unending curiosity about the way things worked. He liked to experiment with different gadgets to see if he could make them work better. He even set up a laboratory in his house, where he conducted experiments.

He invented many objects in his laboratory. His inventions include the phonograph, the first light-bulb, and the first power plant. The power plant — called Edison's Pearl Street Power Station — opened in 1882 in New York City. It sent electricity to 85 customers and made enough power to light 5,000 lamps.

MICHAEL FARADAY

Born in 1791 to a poor family in England, Michael Faraday had an unstoppable curiosity. He became interested in the concept of energy — specifically the issue of force. He conducted many experiments on force and was able to make important discoveries concerning electricity.

He eventually became a famous chemist and physicist. He built two devices to produce electromagnetic rotation — a continuous circular motion from the circular magnetic force around a wire. In 1831, using his “induction ring,” he made one of his greatest discoveries — electromagnetic induction.

This is the induction, or generation, of electricity in a wire by means of the electromagnetic effect of a **current** in another wire. The induction ring was the first electric transformer. Faraday also invented the first generator. From his experiments came devices that led to the modern electric motor, generator, and transformer.

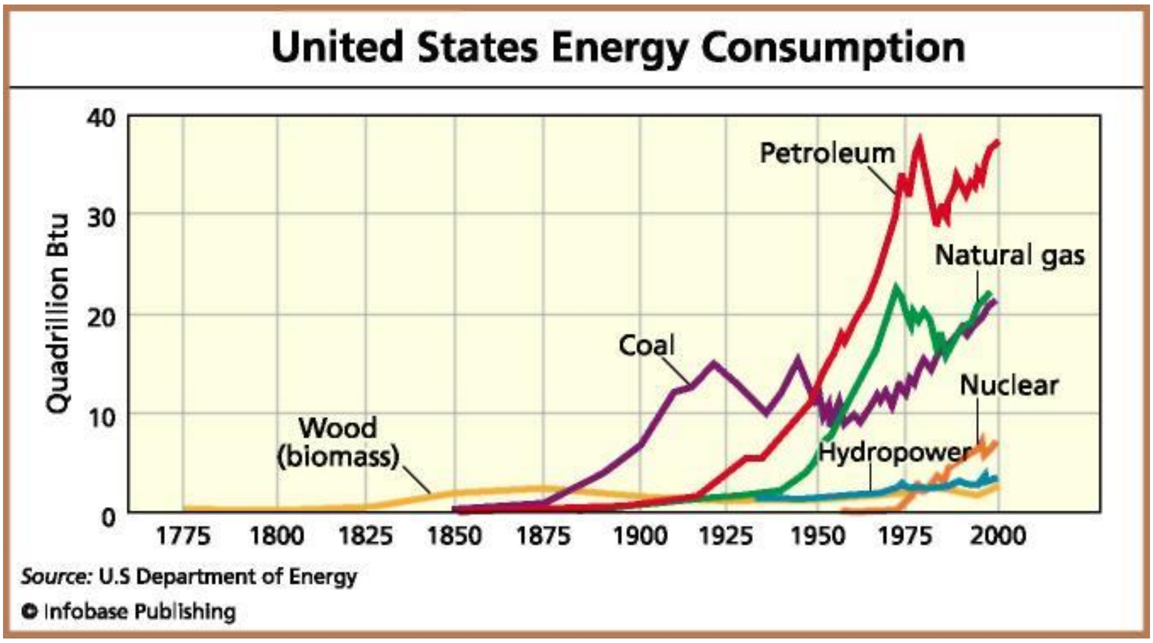
DEVELOPMENT OF ENERGY IN THE UNITED STATES

The United States has always been a resource-rich country, but in 1776 — when the nation declared its independence from Great Britain — nearly all energy was still supplied by muscle power and fuel wood. America’s huge deposits of petroleum and coal lay undiscovered and untapped. There were small amounts of coal being used to produce coke — which was used to cast cannons. The mills constructed at the time used waterpower, and ships used wind power.

Wood energy has been a significant part of the U.S. energy source since colonial times. It was the dominant energy source from the founding of the earliest colonies until the 1800s. Fuel wood use continued to grow, but chronic shortages of energy encouraged the search for other sources. During the first 30 years or so of the nineteenth century, coal began to be used in blast furnaces and in making coal gas for illumination. After that, however, the modern era is noted for the rapid appearance of new sources of energy.

Coal ended the long dominance of fuel wood in 1885. As westward expansion occurred, and railroads were built across the country, the demand for coal increased. It remained the principal energy source until 1951, when petroleum, and then natural gas, became the most used energy source.

Petroleum got its initial start as an illuminant and ingredient in patent medicines but did not catch on as a fuel source right away. Petroleum gained increasing importance with the discovery of Texas's vast Spindletop Oil Field in 1901 and with the advent of mass-produced automobiles — several million of which had been built by 1918. World War II also pushed the popularity of petroleum up because trucks ran on gasoline and diesel fuel.



Wood (biomass) energy has been a significant part of U.S. energy consumption since colonial times. Fuel wood was the dominant energy source from the founding of the earliest colonies until the middle of the 1800s. Coal then became the dominant energy source; but after 1950, petroleum and natural gas have been in greater demand.

Hydroelectric power appeared in 1890, and nuclear electric power appeared in 1957. Solar photovoltaic, advanced solar thermal, and geothermal technologies represent even more recent developments in energy resource evolution.

The most drastic change to society from energy was largely due to Edwin Drake's introduction of petroleum as an energy source. Although the consumption of petroleum did not take off initially, it climbed drastically in the mid-twentieth century. Neither before nor since has any source of energy become so dominant so quickly.

The first half of the twentieth century in the United States marked the shift from muscle power to machine power. Horses, mules, and other draft animals were invaluable up until the mid-1900s. In 1870, draft animals accounted for more than half of the source of power for transportation and machinery. Their displacement by fossil fuel engines meant the disappearance from cities and farms of millions of animals.

As fossil fuels gained a foothold in the economy, the very nature of work evolved along with the fundamental social and political circumstances in the nation. In the middle of the nineteenth century, most Americans lived in the countryside and worked on farms. By the middle of the twentieth century, the United States had become the world’s largest producer and consumer of fossil fuels. Most Americans were city-dwellers, and fewer Americans worked in agriculture. The United States had tripled its per capita consumption of energy and had become a global superpower.

Most of the energy produced today in the United States — as in the rest of the industrialized world — comes from fossil fuels: coal, natural gas, crude oil, and natural gas plant liquids. Fossil fuels together far exceed all other sources of energy.

Throughout its history, the United States has been mostly self-sufficient in energy production, although small amounts of coal were imported from Britain in colonial times. Through the late 1950s, production and consumption of energy were nearly in balance. Over the following decade, however, consumption began to grow more than domestic production.

By the early 1970s, the gap grew even wider — the United States couldn’t produce enough energy to meet the demand. According to the U.S. Department of Energy, in 2000 the United States produced just less than 72 quadrillion Btus of energy and exported 4 quadrillion Btus. The American public, however, consumed 98 quadrillion Btus, requiring 29 quadrillion Btus to be imported — this was 19 times the 1949 level of consumption.

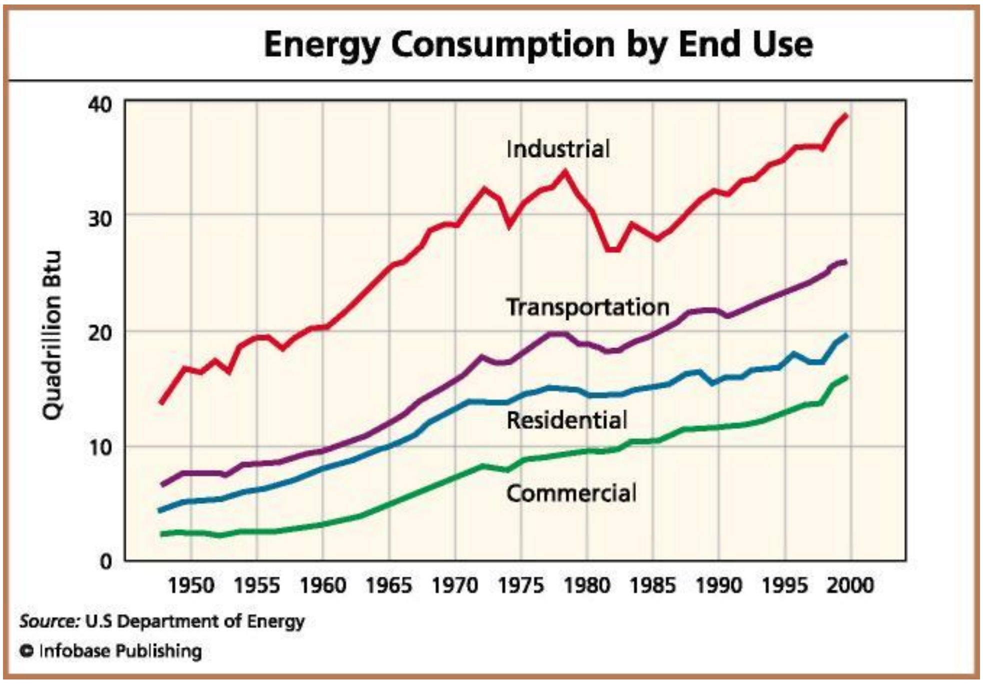
Petroleum demand and consumption is the reason the United States must import so much energy. In 1973, the United States imported 6.3 million barrels per day. In October 1973, the Arab members of the Organization of Petroleum Exporting Countries (OPEC) embargoed the sale of oil to the United States, after which prices rose sharply, and petroleum imports fell for two years. Imports increased again until the price of crude oil rose dramatically (1979-1981) and imports lessened. The rising import trend resumed by 1986 and, except for slight dips in 1990, 1991, and 1995, has continued ever since. In 2000, U.S. petroleum imports reached an annual record level of 11 million barrels a day.

Conservation and efficiency have become a trend in the recent past and the efficiency with which Americans use energy has improved over the years. Even though efficiency has increased, however, energy use has historically continued to rise.

Energy plays a crucial role in the operation of the industrialized U.S. economy, and a lot of energy is used. According to the U.S. Department of Energy, American consumers spend more than half a trillion dollars a year on energy. Energy is categorized into four principal uses: residential, commercial, industrial, and transportation. Over the years, industry has used the most energy.

Energy sources have also changed over the years. In the commercial and residential sectors, coal was the leading source of energy until 1951, but then its use declined rapidly. Petroleum usage grew slowly to its peak in 1972 and then subsided. Natural gas became an important resource, growing strongly until 1972, when its growth drastically slowed. The use of electricity, only an incidental source of energy in 1949, has expanded in almost every year since then and so have the energy losses associated with producing and distributing the electricity.

According to the U.S. Department of Energy, the drastic increase in electricity has happened mainly in the residential sector — reflecting the increased availability, use, and dependence households have on electrical appliances and systems. For example, in 1997, 99% of U.S. households had a color television set and 47% had central air conditioning. Eighty-five percent of all households had one refrigerator; the other 15% had two or more. In 1978, only 8% of U.S. households had a microwave oven, but by 1997, microwaves existed in 83% of the homes. In 1990, 16% of households owned a personal computer; by 1997, the ownership rate had risen to 35%.



Energy consumption in the United States by end use is depicted in the above graph.

Heating homes in the United States has also involved major shifts in energy sources. For example, in 1950, one-third of the homes were heated by coal; but by 1999, that number had dropped to less than one percent. In 2000, the main sources of energy to heat homes shifted to natural gas and electricity. Like residential buildings, most commercial buildings today are also heated by natural gas and electricity.

In the industrial sector, the use of electricity has increased, while the use of coal has decreased, and petroleum and natural gas have fluctuated. More than half the energy consumed in the industrial sector is used for manufacturing, especially in the petroleum, chemical, metal, and paper product industries.

Natural gas is the most commonly consumed energy resource in manufacturing. A relatively small amount of energy is used for other types of manufacturing, such as asphalt roof products, roadbed materials, pharmaceuticals, inks, and adhesives.

Petroleum is the principal source of energy for transportation. Of every 10 barrels of petroleum consumed in the United States in 2000, nearly half were used to make motor gasoline. The five leading suppliers of petroleum to the United States are Saudi Arabia, Canada, Venezuela, Mexico, and Nigeria (Source: U.S. Department of Energy, Energy Information Administration).

Electricity has become an increasingly significant energy resource in the United States. Most electricity is produced from coal (which provides more than half of the electricity generated), hydroelectric power, natural gas and petroleum, and nuclear power.

Just as electricity's applications and sources have changed over time, the structure of the electric power sector is also evolving. It is moving away from the traditional, highly regulated organizations known for decades as electric utilities toward an environment marked by lighter regulation and greater competition from non-utility power producers. Based on data from the U.S. Department of Energy, in 2000, non-utility power producers produced 26% of the total electricity made available.

Modern renewable sources (such as wind, water, and wood) in the United States contribute about as much to total energy consumption, as does nuclear power. Hydroelectric power generation, which uses the water stored in reservoirs behind dams to drive turbine generators, accounts for a large share of U.S. renewable energy output.

Much of U.S. renewable energy today comes from wood and waste. These energy sources include: wood, methanol, ethanol, peat, wood liquors, wood sludge, railroad ties, pitch, municipal solid waste, agricultural waste, straw, tines, landfill gas, and fish oil. Wood and its by-products are the most heavily used form of biomass and are an important source of energy for such industries as lumber and paper manufacturing. Geothermal energy accounted for 5% of the U.S. renewable energy in 2000.

Solar energy (photovoltaic and thermal) and wind energy contribute least of all to the renewable energy sector — only about 2% in 2000. Most of the solar thermal collectors (91%) went for residential uses, and most of these were used to heat swimming pools. Four percent were used to heat water. Wind energy production rose 113% between 1989 and 2000, but it is still a small component of renewable energy use in the United States.

RENEWABLE and NON-RENEWABLE RESOURCES

There are two general classes of resources: **renewable** and **non-renewable**. A renewable resource is a resource that can be replenished. It is a resource that can be replaced by natural ecological cycles, Earth system cycles, and good management practices. The opposite of this is a nonrenewable resource — a resource that cannot be replenished (once it is gone, it is gone for good).

For practical applications, scientists consider a renewable resource one that can be replenished within one generation of a human’s lifetime (approximately 20-30 years). Resources such as fossil fuels and nuclear energy (uranium) are nonrenewable. Even though the same geologic processes that form them are still happening on the Earth today, these resources will not be replaced within our lifetime because they take millions of years to form. As a result, they are not renewable resources for the present life on Earth.

Even though there are many different types of energy resources, they fit into either a nonrenewable or renewable category. Nonrenewable resources are the fossil fuels and uranium (for nuclear energy). They are the resources being depleted because of constant use. On the other hand, there is no shortage of renewable energy from the sun, wind, and water. Even what is usually thought of as garbage — dead trees, branches, lawn clippings, sawdust, livestock manure, and leftover crops (called biomass) — can produce electricity.

NON-RENEWABLE ENERGY RESOURCES

Nonrenewable energy sources come out of the ground as liquids, gases, and solids. Crude oil (petroleum) is the only naturally liquid commercial fossil fuel. Natural gas and propane are normally gases, and coal is a solid stored in beds.

The United States currently gets 88% of its energy from fossil fuel energy sources (Source: U.S. Department of Energy, Energy Information Administration). Fossil fuels — primarily coal, oil, and natural gas — were formed hundreds of millions of years ago, before the time of the dinosaurs, from decomposed plant and animal matter. When fossil fuels are burned, they release greenhouse gases and other pollutants into the atmosphere.

Uranium ore, a solid, is mined and converted to a fuel. Uranium is not a fossil fuel — it is a radioactive, metallic element. Nuclear energy, also a nonrenewable resource, provides about 8% of the energy in the United States. Its radioactive fuel — typically uranium — is used up in the process of energy production, and the spent radioactive waste must then be stored for tens of thousands of years before it becomes safe. Because of this, there is a high amount of controversy over the use of nuclear power.

Oil (petroleum)

Oil was formed from the remains of animals and plants that lived millions of years ago in a marine (wet) environment. Over the years, layers of mud covered the remains. Heat and pressure from these layers helped the remains turn into what is referred to as “crude” oil. The word *petroleum* means “rock oil” or “oil from the Earth.”

Crude oil is a yellow-to-black liquid and is usually found in large underground areas called reservoirs. Scientists and engineers explore a chosen area by studying rock samples from the Earth. Measurements are taken, and if scientists believe it is a formation that contains oil, drilling begins. Above the hole, a triangular structure called a derrick is built to house the tools and pipes that go into the well. Once a well is drilled to the correct depth, a steady flow of oil comes to the surface.

Much of the crude oil in the United States comes from California, Texas, and Louisiana — much of it produced offshore. Even though the United States is one of the world's major oil producers, more than 60% of the crude oil and petroleum products used in the United States are imported from other countries.

After crude oil is removed from the ground, it is sent to a refinery by pipeline, ship, or barge. At a refinery, different parts of the crude oil are separated into usable petroleum products. Crude oil is measured in barrels.

A 42-U.S.-gallon (158 liter) barrel of crude oil provides a little more than 44 gallons (167 liters) of petroleum products. This 2-gallon (9 liter) gain happens when the crude oil is processed. One barrel of crude oil, when refined, produces 19.9 gallons (75.3 liters) of motor gasoline along with other petroleum products.

Most of the petroleum products are used to produce energy — to fuel airplanes, cars, and trucks. Other common products are also made from petroleum, such as ink, bubble gum, crayons, deodorant, dishwashing liquid, eyeglasses, ammonia, tires, records, makeup, plastic products, heart valves, and medicine. Products from oil are used every day in many ways.

What a Barrel of Gas Represents

In the early 1860s, when oil production began, there was no standard container for oil, so oil and petroleum products were stored and transported in barrels of all different shapes and sizes, such as beer barrels, fish barrels, molasses barrels, and turpentine barrels. By the early 1870s, the 42-gallon (158 liter) barrel had been adopted as the standard for oil trade — 2 gallons (9 liters) more than the 40-gallon (149 liter) barrel that had been previously adopted as the standard for oil trade.

This extra oil was to allow for **evaporation** and leaking during transport (most barrels were made of wood). Standard Oil began manufacturing 42-gallon (158 liter) barrels, that were blue, to be used for transporting petroleum. The use of a blue barrel — abbreviated *bbl* — guaranteed a buyer that this was a 42-gallon (158 liter) barrel.

There are environmental impacts associated with petroleum, however, such as air and water pollution. Over the years, as people have become more environmentally aware, new technologies and laws have been put in place to reduce the negative impacts.

Because petroleum has an impact on the environment, the federal government monitors its production, refinement, transportation, and storage. Since 1990, fuels made from petroleum have been improved so that they produce lower amounts of pollution.

Because exploring and drilling for oil can also adversely impact land and ocean habitats, new technology has been developed in recent years to reduce the disturbance. The use of space satellites, global positioning systems, remote sensing (aerial photos and satellite images), and 3-D and 4-D seismic technologies allow engineers and scientists to discover and explore new wells without harming the surrounding natural environment.

Due to the invention of movable drilling rigs and smaller drilling rigs, today's production impact is only about one-fourth of what it was 30 years ago, according to experts at the U.S. Department of Energy.

When all the oil from a well is gone, the well is plugged below ground. Some offshore rigs are then knocked over and left on the sea-floor to become artificial reefs that attract fish and other marine life, such as coral, sponges, and barnacles.

If oil is spilled into rivers or oceans, it can harm wildlife. Leakage from ships has been reduced since the 1990s, when ships were required to have a "double hull" lining to protect against spills. The largest percentage of oil that leaks into water is from natural oil seeps coming from the ocean floor.

Fuel can also leak from motor boats and jet skis and enter the water. Oil products used on land (such as used motor oil) can eventually get washed downstream to contaminate rivers and oceans.

Natural Gas

Natural gas is formed the same way as petroleum – from the remains of ancient plants and animals. Over time, pressure and heat from the Earth changed some of this organic material into natural gas – tiny bubbles of odorless gas. The main ingredient in natural gas is methane, a gas composed of one carbon atom and four hydrogen atoms.

Gas escapes from small spaces in the rocks into the air. When people first saw flames emitted from natural gas areas during electrical storms, they experimented with the gas and discovered how natural gas could be used.

Natural gas is found in geologic settings similar to where petroleum occurs. Geologists use seismic surveys to locate likely areas to drill for gas deposits. They commonly use seismic surveys, which use vibrations on the Earth's surface to send out echoes and collect information about the rocks beneath the ground. If a site looks promising, the area is drilled. Many of the nation's drilling rigs are offshore, deep in the ocean. Once gas is found, it flows up through the well to the surface of the ground and then into large pipelines.

Some of the gases produced — besides methane — are butane and propane. Propane can be used to heat homes or cook food on a barbecue grill. Because natural gas is naturally colorless, odorless, and tasteless, mercaptan (a chemical that smells like sulfur) is added to it as a safety precaution in case of a leak (a natural gas leak can be fatal if a person breathes it in).

Other machines, called "digesters," turn organic material — such as food, plants, animal waste, and garbage composed of these materials — into natural gas. Natural gas is also a raw material for many products used every day, such as paint, fertilizer, antifreeze, plastic, dyes, photographic film, medicines, and explosives. Natural gas has thousands of uses. It is used to produce steel, glass, paper, clothing, brick, and electricity. According to the U.S. Department of Energy, more than 61.9 million homes use natural gas to fuel furnaces, water heaters, and clothes dryers.

Natural gas is one of the “cleaner” fossil fuels because it produces fewer pollutants. It also has fewer emissions than coal or oil and does not release ash particles after it is burned.

Coal

Millions of years ago, huge forests covered the Earth’s surface. Some of the forests were later covered by water. The plants died and formed a thick layer of vegetative matter. As it hardened, this layer became peat. Through time, layers of soil and sediment covered the peat. Buried under heavy layers of sediment, the peat was protected from the air. Over many years, the peat was transformed into coal.

Throughout geologic time, this process happened repeatedly, which formed distinctive beds of coal. Layers of buried coal are also called coal seams or coal veins. Coal seams usually lie parallel to the Earth’s surface, which means the oldest coal is buried the deepest — unless geologic processes have disturbed it and tilted it.

Coal that is mined near the surface of the ground is done using a technique called strip mining, also called open cast mining. Miners dig the coal from an exposed seam. Deeper seams are mined using underground tunnels.

According to the U.S. Department of Energy, the United States produces more than one-fifth of the world’s coal. Coal is used to generate more than half of all electricity produced in the United States. It is also used as an energy source in the steel, cement, and paper industries. Most U.S. coal beds are located near the ground’s surface. Modern mining methods allow easy access to these reserves. Coal is used for four main purposes: for the generation of electric power, for industry, for making steel, and as an export commodity.

Power plants burn coal as a fuel in order to produce steam. The steam is necessary to turn turbines, which generate electricity. Electric utility companies use more than 90% of the coal mined in the United States. Many industries use coal’s heat and by-products. Separated ingredients of coal (such as methanol and ethylene) are used in making plastics, tar, synthetic fibers, fertilizers, and medicines. According to the Energy Information Administration of the U.S. Department of Energy, industry uses more than 6% of the coal mined in the United States.

Coal is baked in hot furnaces to make coke, which is used to smelt iron ore into the iron needed for making steel. The extremely high temperatures created for the use of coke gives steel the strength and versatility it requires for use in products such as bridges, buildings, and automobiles.

Coal strip mining, oil refinery, and manufacturing.
(a) The predominant underground mining method in the United States is the room and pillar method, a term derived from the mining pattern of a series of excavated areas (rooms) and unexcavated areas (pillars) which are left to support the roof.

(b) Miners are protected by the Thyssen roof supports. The canopy extensions are hydraulically operated. The shield supports weigh 17.5 tons (15.9 metric tons) and measure 16.5 feet (5 m) in length.

(c) Oil refinery in Salt Lake City, Utah.

(d) Manufacturing plants require enormous amounts of power, like this metal-producing plant.

(a, b, courtesy of U.S. Department of Energy; c, d, photos by Nature's Images)

The Differences Between Peat, Lignite, Bituminous Coal, and Anthracite

As decaying matter becomes coal, it passes through several stages. The first stage is peat, which forms when layers of plant matter harden. At this point, it does not contain much carbon, so it gives off a lot of smoke when it is burned. After burning, it leaves behind large quantities of ash. Huge deposits of peat are referred to as peat bogs. Peat is used in some countries to heat homes. It is also used as a fuel in factories.

Lignite comes from peat deposits that have been confined under pressure. It is not as black or as dense as other coals. It is more loose-grained and has less carbon, so it does not heat as well as other forms of coal. When lignite is buried under deep pressure, it changes into bituminous coal — the most common type of coal. It is black, sooty, has a high degree of carbon, and burns well.

The oldest stage of coal is anthracite – the hardest of all the coals. It is shiny and clean. It is rich in carbon, burns slowly, leaves no ash behind, gives off a lot of heat, and lasts a long time.

Uranium and Nuclear Energy

The U.S. Department of Energy has determined that nuclear power accounts for about 20% of the total electricity generated in the United States, an amount comparable to all the electricity used in California, Texas, and New York. In 2003, there were 66 nuclear power plants throughout the United States, located mostly on the East Coast and in the Midwest.

A nuclear power plant operates basically the same way as a fossil fuel plant, with one difference: the source of heat. The process that produces the heat in a nuclear plant is the fissioning — or splitting — of uranium atoms. That heat boils water to make the steam that turns the turbine generator, just as in a fossil fuel plant. The part of the plant where the heat is produced is called the reactor **core**.

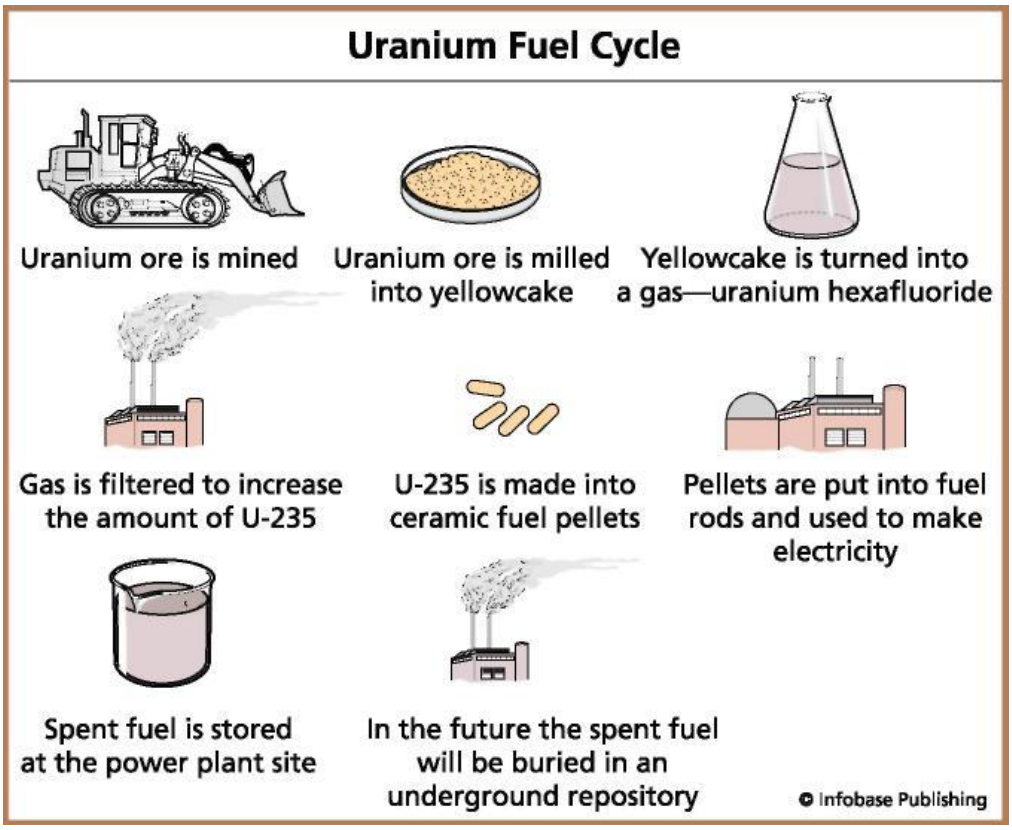
Atoms are made up of three major particles: protons, neutrons, and electrons. The most common fissionable atom is an isotope (the specific member of the atom's family) of uranium known as Uranium-235 (U-235 or U^{235}), which is the fuel used in most types of nuclear reactors today. Although uranium is fairly common — about 100 times more common than silver — U^{235} is relatively rare.

Most U.S. uranium is mined in the western United States. Once uranium is mined, the U^{235} must be extracted and processed before it can be used as a fuel. In its final usable state, the nuclear fuel will be in the form of a pellet roughly 1 inch (2.54 centimeters) long, which can generate approximately the same amount of electricity as 1 ton (0.91 metric tons) of coal.

There are different types of nuclear power plants. Two types are used in the United States: boiling-water reactors (BWRs) and pressurized water reactors (PWRs). In the BWR, the water, heated by the reactor core, turns directly into steam in the reactor vessel and is then used to power the turbine generator.

In a PWR, the water passing through the reactor core is kept under pressure so that it does not turn to steam at all — it remains liquid. Steam to drive the turbine is generated in a separate piece of equipment called a steam generator. A steam generator is a giant cylinder with thousands of tubes in it through which the hot, radioactive water can flow.

Outside the tubes in the steam generator, nonradioactive water ("clean" water) boils and eventually turns to steam. The clean water may come from one of several sources — oceans, lakes, or rivers. The radioactive water flows back to the reactor core, where it is reheated, only to flow back to the steam generator. Roughly 70% of the reactors operating in the United States are PWR.



The uranium fuel cycle.

Nuclear reactors are basically machines that contain and control chain reactions, while releasing heat at a controlled rate. In electric power plants, the reactors supply the heat to turn water into steam, which drives the turbine generators. The electricity is shipped or distributed through transmission lines to homes, schools, hospitals, factories, office buildings, rail systems, and other customers.

The reactor core is composed of four main elements: fuel, **control rods**, coolant, and a **moderator**. The nuclear fuel is stored in fuel rods. The fuel consists of pellets of enriched uranium dioxide that are packed into thin metal rods roughly 12 feet (3.7 m) long. Large groups of these rods can be connected in order to allow the power plant to operate for long periods of time.

The control rods are used to regulate (control) the rate of the nuclear chain reaction. For example, if they are pulled out of the core, it speeds up the reaction. Conversely, if they are inserted, the reaction slows down.

A coolant — usually water — is pumped through the reactor to carry away the extreme heat generated by fissioning of the fuel in the nuclear reaction. This is comparable to the water in the cooling system of a car, which carries away the heat built up in the engine. A moderator is used to slow down the speed at which energized atoms travel. Water is commonly used for this purpose. This is important because reducing the speed enables atoms to be more likely to split. This splitting is what releases the energy.

Although it may seem like a highly efficient and clean method of producing energy, nuclear power generation does have by-product wastes associated with it in the forms of radioactive waste and hot water.

On the positive side, based on studies conducted by the U.S. Department of Energy, because nuclear-generated electricity does not emit **carbon dioxide** into the atmosphere, nuclear power plants in the United States prevent about as much greenhouse emissions as taking 5 billion cars off the streets and highways.

Radioactive wastes are the principal environmental concern about using nuclear power. Most nuclear waste is low-level nuclear waste: ordinary trash, tools, protective clothing, wiping cloths, and disposable items that have been contaminated with small amounts of radioactive dust or particles. These materials are subject to special regulations that govern their storage so they will not come in contact with the outside environment.

The irradiated fuel assemblies are highly radioactive and must be stored in specially designed pools resembling large swimming pools (water cools the fuel and acts as a radiation shield) or in specially designed dry storage containers. The older and less radioactive fuel is kept in a dry storage facility, which consists of special concrete-reinforced containers.

The U.S. Department of Energy's long-range plan is for this spent fuel to be stored deep in the Earth in a geologic repository, at Yucca Mountain, Nevada. Currently, all spent (used) fuel is stored at the power plant at which it was used.

Oil Shale, Tar Sands, and Natural Bitumen

Oil shales are natural rock formations that contain deposits of kerogen (a type of organic matter), which can be converted into a product resembling petroleum. The term *oil shale* is somewhat misleading, however, because sometimes the rock layer in which the kerogen is trapped is not actual shale, but a rock called *marl.*

Natural oil is formed through physical processes that generate great amounts of heat within the Earth's crust. Because oil shale is not subject to these physical processes naturally, it must be artificially heated to a high temperature in order to transform it into a liquid. Scientists believe the oil product produced from oil shale has a quality somewhere between natural oil's low- and high-grade distinctions. Many of the richest oil shale deposits in the world occur in the western United States, in states such as Utah.

There are two ways of processing oil shale. In one method, the rock is fractured in place and heated to obtain the gases and liquids by wells. The second way is by mining, transporting, and heating the shale to about 232°F (450°C), adding hydrogen to the resulting product, and disposing of the waste.

Both of these processes use an excessive amount of water. To date, the financial and environmental costs — costs of blasting, transporting, crushing, heating, and adding hydrogen, as well as the safe disposal of huge quantities of waste material — are great enough that large-scale production has not occurred yet in the United States. Oil shale has been used as a low-grade fuel in Estonia and other countries by burning it directly. Unfortunately, this produces a fuel that is high in ash content and harmful to the environment.

Worldwide, use of this fuel is still very limited. According to the U.S. Department of Energy, however, with the current prices of petroleum continuing to rise, oil shale production may be looked at closer as a way to offset the daily consumption of 73 million barrels of oil worldwide. Currently, however, on a small scale, oil shale may be able to make a contribution to the world's energy needs, but so far it is not a viable choice of energy.

Tar sands are sands infused with heavy oil that require further processing to refine into petroleum products. Some deposits are so heavy that they can be mined more easily than pumped.

Tar sands are a mixture consisting of a host sedimentary porous rock of mineral material (usually sand, sandstone, limestone, carbonate rock, or diatomaceous earth), which contains a form of heavy asphalt-like crude oil that is too viscous (thick) to flow through rocks, well bores, or pipelines or to recover by conventional pumping methods.

Although most tar sand deposits are mined, they can also be pumped after high-pressure steam is injected underground to separate the valuable oil from the sand. Hydrogen is added later to turn it into a synthetic crude oil. Producing oil from tar sands is energy intensive, however. The equivalent of one barrel of oil is needed to process three barrels of synthetic crude oil. Production of conventional oil still requires much less energy. Besides being energy intensive, another drawback is that a large amount of waste sand is generated. Using tar sand also contributes to the greenhouse gases in the atmosphere.

The American Association of Petroleum Geologists has determined that tar sands are currently found in about 70 countries around the world. The world's largest deposits are in Canada and Venezuela, and may prove to be critical over the next 50 years to the supply of liquid fuels as the world's production of traditional oil lessens. It will not ultimately solve the need for petroleum, but it may — in the future — provide an avenue to develop new technologies and cleaner fuels.

According to journalist Thomas J. Quinn of the *Cleveland Plain Dealer,* some energy analysts believe emergency programs need to be put in place in order to experiment with, and learn to use, tar sands as an energy source. They believe the peak of oil production will happen sometime between now and the year 2030. Some experts believe Canada may have close to 180 billion barrels of tar sand — roughly a six-year world supply at today's energy consumption rates.

Tar sand production is around 1 million barrels a day and is projected to be five times as much by the year 2030 — which is only half of Saudi Arabia's current output of petroleum and less than 5% of world production predicted for 2030. Supporters of tar sand development admit that the technology to use it must be further developed for it to have a significant impact on worldwide energy use.

Natural bitumen and extra-heavy oil are two types of petroleum. Because the lighter elements comprising petroleum are not found in these deposits, they have a higher percentage of heavy **molecules**, making them more dense and viscous (thick).

Natural bitumen and extra-heavy oil occur worldwide. According to the World Energy Council in 2005, the largest bitumen deposit is located in Alberta, Canada, and accounts for about 85% of the world total. Energy experts believe that it may be the only deposit in the world large enough to recover and convert to oil economically. The extra-heavy crude oil deposit of the Orinoco Oil Belt in Eastern Venezuela represents nearly 90% of the known extra-heavy oil in place.

Natural bitumen is also contained in bituminous sands, oil shale, and tar sands. In order to recover it, the petroleum is obtained either as raw bitumen in place or as a synthetic crude oil processed through refinement. So far, these resources have not been explored fully or had their extraction and processing developed in order to be economical. As future energy demands rise and oil becomes scarcer, these forms of energy will become more important to develop.

RENEWABLE ENERGY

Renewable resources offer an immense potential supply of energy. According to the government of California, that state has enough energy in wind gusts to produce 11% of the world's wind electricity. The sunlight that falls on the United States in one day contains more than twice the energy the United States consumes in a whole year. Renewable energy resources are also referred to as "clean" energy. These sources can be harnessed to produce electricity, heat, fuel, and chemicals that are much more environmentally friendly.

As a comparison, emissions from cars that burn gasoline and emissions from industrial factories that use fossil fuels contribute greatly to the greenhouse effect. Experts at the U.S. Environmental Protection Agency believe that about 80% of all the greenhouse gases in the United States are the result of these energy-related sources.

Using renewable energy not only helps the environment, but it helps the economy. Developing and using renewable sources keeps more money at home to bolster the economy of the United States. Also, the more nonrenewable sources that are provided locally, the less energy (fossil fuels) that must be imported from foreign countries. In addition, in this time of such political instability with many of the oil-producing countries in the Middle East, having to import less oil relieves some of the international political tension that currently exists.

Another positive trend with renewable energy resources is that with continued research, development, and experimentation, these sources are becoming more affordable. There are also drawbacks, however. For example, solar energy requires large available areas of land, which can impact wildlife habitat, disturb land use, and degrade the land through construction of roads and buildings. Also, the photovoltaic cells are manufactured using toxic chemicals. In addition, the United States does not currently have enough solar production facilities to meet the current energy demand.

Wind power also requires the use of large areas of land, can cause erosion, and can impact wildlife habitat by being a constant danger to birds. Geothermal energy is restrictive because geothermal sites only occur in a limited number of places. In addition, the steam can be caustic and corrode the pipes used in energy production.

Hydroelectric power has its drawbacks, too. It causes certain areas of land to become permanently submerged, can impact wildlife habitat, and can cover archaeological sites. Downstream, dams can change the chemical, physical, and biological characteristics of the river and land. Although these renewable sources have some drawbacks – generally, usage of large areas of land that affect animal habitats and outdoor scenery — they have much less impact on the environment than nonrenewable sources.

Solar Energy

The Sun has produced energy for billions of years. Solar energy can be converted directly or indirectly into other forms of energy, such as heat and electricity. The major drawbacks of solar energy include the following: (1) the intermittent and variable manner in which it arrives at the Earth's surface and (2) the large area required to collect it at a useful rate.

Solar energy is used for heating water for domestic use, space heating buildings, drying agricultural products, and generating electrical energy. Electric utilities are trying photovoltaic technology, a process by which solar energy is converted directly to electricity.

Electricity can be produced directly from solar energy using photovoltaic devices or indirectly from steam generators using solar thermal collectors to heat a working fluid. Photovoltaic energy is the conversion of sunlight into electricity.

This is accomplished with a device called a photovoltaic (PV) cell — also referred to as a solar cell. A PV cell is composed of silicon alloys. When photons (particles of solar energy) strike a PV cell, different responses can occur — they may either be reflected, pass through, or become absorbed by the surface.

The photons that are absorbed are the critical ones in the photovoltaic process, because the absorbed photons provide the necessary energy to generate electricity. When enough photons are absorbed, the electrons of the surface material of the cell are separated from the atoms. Because of the way the PV cells are produced, more electrons are attracted to the front surface in order to generate energy.

Electrons carry a negative charge. Therefore, when they migrate to the front surface of the PV cell, it causes an imbalance in the distribution of the charge, which in turn creates a voltage (the potential energy that pushes a current around an electric circuit).

Because each individual cell only produces a small amount of electricity (1 to 2 watts), PV systems must be made of multiple joined individual cells. When large groups of individual PV cells are connected in formations called modules or arrays, the combined voltage creates usable electricity. An array refers to the entire generating plant, which can be made up from one to several thousand modules.

The amount of electricity produced from a photovoltaic array depends on the amount of available sunlight (it is the photons from the sunlight that enable the creation of electricity). For example, if the skies are overcast, the amount of sunlight is reduced, causing less photons to reach the array, which in turn lowers the amount of electricity the PV array can create.

Conversely, clear skies ensure a constant source of sunlight, enabling the array to be highly productive. With today's technology, photovoltaic modules are about 10% efficient in converting available sunlight into energy. Scientists believe that further research on PV arrays will increase their efficiency.

PV cells have had many uses over the years in scientific applications. For instance, in the late 1950s, they were used to provide the power to operate U.S. space satellites. Based on their successful use in space, scientists were then able to use this information to create several commercial applications on Earth. PV cells are commonly used today in calculators and wrist watches, as well as to provide electricity to homes and to power equipment.

The appeal of photovoltaic energy lies in the fact that because the conversion from sunlight to electricity is direct, it eliminates the need to use bulky mechanical generators. They are also portable, easy to assemble, and adjustable, which allows arrays to be installed quickly and in the required configuration for the specific application.

A photovoltaic system is appealing from an environmental standpoint. The impact of a photovoltaic system on the environment is minimal because it does not produce any harmful by-products, and precious water resources do not have to be used for system cooling (as is the case with some other energy sources). They can also generate the direct current (DC) necessary for the operation of electronic equipment. PV cells have also been used to provide electricity for remote sites where installing traditional electric lines is neither not feasible nor economical.

The major applications of solar thermal energy today are for heating swimming pools, heating water for domestic use, and heating the insides of buildings. The solar panels are flat-plate solar-energy collectors installed in a fixed position.

The highest efficiency is reached when the collector faces toward the south and is inclined horizontally to the location's latitude plus 15 degrees — an angle that best captures the incoming solar energy for that particular point on Earth. For example, a solar-heated home located at a latitude in the United States of 45 degrees would have their solar panels inclined at 60 degrees for the highest efficiency.

Solar collectors can be non-concentrating or concentrating. In the non-concentrating type, the collector area (the area that intercepts the solar radiation) is the same as the absorber area (the area absorbing the radiation). This method is commonly used in space heating. In concentrating collectors, the area intercepting the solar radiation is greater than the absorber area. These collectors are used for applications that require higher energy levels.

Solar space-heating systems can also be classified as passive or active. In a passive heating system, the air is circulated past a solar heat surface and through the building by **convection** without the use of mechanical equipment. In active heating systems, mechanical equipment (such as fans and pumps) are used to circulate the warm air or fluid.

Solar thermal power plants use the Sun's rays to heat a fluid, from which heat-transfer systems are used to produce steam, which is then converted into mechanical energy in a turbine. A generator connected to the turbine produces the electricity. The appeal of solar thermal power plants is that the burning of fossil fuels is not necessary. Therefore, these types of power plants do not pollute the environment. There are three types of solar thermal power systems — the parabolic trough, solar dish, and solar power tower.

A parabolic trough is the most advanced of the concentrator systems and is used in large grid-connected power plants. A solar dish uses concentrating solar collectors, which track the Sun's path in the sky, ensuring the dish is always pointed toward the Sun. A solar power tower generates electricity from sunlight by focusing concentrated solar energy on a centrally located, large, tower-mounted receiver.

This system can use hundreds to thousands of flat sun-tracking mirrors called heliostats in an array around the tower to reflect and concentrate the Sun's energy onto the central receiver. Power towers are still under development, however, as scientists experiment with the technology, enabling it to be more economical.

Wind Energy

Wind is air in motion. It is produced by the uneven heating of the Earth's surface by the Sun. Since the Earth's surface is made of various land and water formations, it absorbs the Sun's radiation unevenly. This is what causes the uneven heating to occur.

When the Sun is shining during the day, the air over landmasses heats more quickly than the air over water. Because warm air is lighter and subsequently rises, it is replaced by the cooler and heavier air that was initially over the water's surface. This process of the air moving across the ocean toward land causes the air to circulate. It is this simple process that creates the local wind system of an area.

At night, the winds are reversed because the air cools more rapidly over land than over water. Based on the same principle, the large atmospheric winds that circle the Earth are created because the surface air near the equator is warmed more by the Sun than the air over the North and South Poles.

This process is constantly occurring. Because of this, wind is considered a renewable energy resource; it will continually be produced as long as the Sun shines on the Earth — the heat from the sun is the engine that drives the global force. Today, wind energy is typically used to generate electricity.

Windmills work because they slow down the speed of the wind. The wind flows over the airfoil-shaped blades, which causes lift — like the effect on airplane wings in flight — and causes them to turn. The blades are connected to a driveshaft that turns an electric generator to produce electricity.

Today's wind machines are much more technologically advanced than the early windmills. They still use blades to collect the wind's kinetic energy, but the blades are made of fiberglass or other high-strength materials. Modern wind machines are still dealing with the problem of what to do when the wind is not blowing. Large turbines are usually connected to the utility power network — so that some other type of generator picks up the load when there is no wind. Small turbines are sometimes connected to diesel/electric generators or sometimes have a battery to store the extra energy they collect when the wind is blowing hard.

Two types of wind machines are commonly used today — the horizontal-axis with blades like airplane propellers and the vertical-axis, which resembles an egg beater. Horizontal-axis wind machines are more common because they use less material per unit of electricity produced.

According to the U.S. Department of Energy, about 95% of all wind machines in use today are the horizontal-axis type. These wind machines are huge. A typical horizontal wind machine stands as tall as a 20-story building and has three blades that span 200 feet (61 m) across.

The largest wind machines in the world have blades longer than a football field (300 feet or 91.4 m). Wind machines stand tall and wide to capture more wind. Vertical-axis wind machines make up only 5% of the wind machines used today. The typical vertical wind machine stands 100 feet (30 m) tall and 50 feet (15 m) wide.

Each type of wind machine has its advantages and disadvantages. Horizontal-axis machines need a way to keep the **rotor** facing the wind. This is done with a tail on small machines. Large turbines use either a rotor located downwind of the tower to act like a weather vane, or they use a drive motor. Vertical-axis machines can accept wind from any direction.

Both types of turbine rotors are turned by air flowing over their wing-shaped blades. The vertical-axis blades lose energy as they turn out of the wind, while horizontal-axis blades work all the time. At many sites, the wind speed increases higher above the ground, giving an advantage to tall horizontal-axis turbines. The small tower and ground-mounted generators on vertical-axis turbines also make them cheaper and easier to maintain.

It takes more than one wind machine, however, to produce large amounts of usable energy. Commonly, dozens of wind machines exist in a wind farm array. Interestingly, unlike traditional coal-fired power plants, which are owned by public utility companies, many of today's wind farms are owned by private companies.

These independent producers then sell the electricity they produce to electric utility companies, which in turn sell it to their customers. Many customers choose to buy this energy (even though it is slightly more expensive) in order to reduce the known negative impacts on the environment from using fossil fuel energy sources.

Wind power plants cannot be placed in just any random, convenient location, however. Their location must be based on specific factors, such as wind availability (how much the wind blows), local weather conditions, proximity to electrical transmission lines, and local zoning codes.

Economics must also be considered, because once a plant has been built, there are maintenance costs. In some states, these costs are offset by tax breaks given to power plants that use renewable energy sources. The Public Utility Regulatory Policies Act, or PURPA, also requires utility companies to purchase electricity from independent power producers at rates that are fair and nondiscriminatory.

Location is one of the most important factors in developing wind farms. Areas where the wind is strong and continuous are the most desirable. The United States has several areas where these conditions apply, such as California, Alaska, Hawaii, the Great Plains, and mountainous regions. In order to generate efficient electricity from wind energy, the wind must have an average speed of 14 mph (22.5 km/h).

There are two different ways to measure the energy the wind provides: efficiency and capacity. Efficiency refers to how much useful energy (such as electricity) can be generated from an energy source.

A 100% energy-efficient machine would change all the energy put into it into useful energy. It would not waste any energy. There is no such thing as a 100% energy-efficient machine, however. Some energy is always lost or wasted when one form of energy is converted to another.

The lost energy is usually in the form of heat, which dissipates into the air and cannot be used again economically. In terms of efficiency, however, wind machines are just as efficient as most other traditional energy plants, such as coal plants.

According to the U.S. Department of Energy, wind machines convert 30%–40% of the wind's kinetic energy into electricity. A coal-fired power plant converts about 30%–35% of the chemical energy in coal into usable electricity.

Capacity refers to the capability of a power plant to produce electricity. A power plant with a 100% capacity rating would run all day, every day, at full power. There would be no downtime for repairs or refueling. These types of power plants do not exist. Coal plants typically have a 75% capacity rating since they can run day or night, during any season of the year.

Wind power plants are different from power plants that burn fuel. Wind plants depend on the availability of wind, as well as the speed of the wind. Therefore, wind machines cannot operate 24 hours a day, 365 days a year.

A wind turbine at a typical wind plant operates 65%-80% of the time, but usually at less than full capacity, because the wind speed is not at optimum levels or it is sporadic. Therefore, its capacity factor is 30%-35%.

Economics also plays a large part in the capacity of wind machines. Wind machines that have much higher capacity factors can be built, but it is not economical to do so — yet.

Based on studies conducted by the U.S. Department of Energy, one wind machine can produce 1.5 to 4.0 million kilowatt-hours (kWh) of electricity each year. That is enough electricity for 150-400 homes.

In the U.S., wind machines currently produce 10 billion kWh of energy a year. While this may seem like a lot, wind energy only provides about 0.1% of the nation's electricity — a very small amount. That is enough electricity to serve a million households (an area roughly comparable to a city nearly the size of San Diego, California, or Dallas, Texas).

California produces more electricity from the wind than any other state, followed by Texas, Minnesota, and Iowa. California alone has approximately 13,000 wind machines that produce more than 1% of the State's electricity. They expect that within the next 15 years, wind energy may be able to generate 5% of the needed electricity. The reason California is currently in the lead in wind technology innovation and implementation is due to the positive initiatives that California's state government has taken to support renewable energy in an effort to protect the environment.

There are other states that have wind resources comparable to California's. In fact, ten years ago, the United States was the world's leading producer of wind energy — producing 90% of the world's wind-blown electricity.

By 1996, however, that number had dropped to 30%. Wind is the fastest-growing energy technology in the world today. Experts expect the production from wind machines to triple in the next few years. Other areas of the world, including India and many European countries, are planning future wind facilities.

Unfortunately, in the United States, wind capacity grew very slowly in the 1990s. Many new wind projects were put on hold because of electricity deregulation. Because utility providers were not sure how deregulation would affect many new technologies, it caused wind technology to come to a temporary standstill.

Fortunately, recent investment in wind energy is beginning to increase because its cost has come down and the technology has improved, making wind one of the most competitive new sources for energy generation.

Another positive sign for the wind industry is the growing consumer demand for "green" pricing. Many utilities around the country now allow customers to voluntarily choose to pay more for electricity generated by renewable sources as an effort to protect the environment. Energy experts believe wind energy will become more in demand in the future.

In the 1970s, oil shortages spurred the development of alternative energy sources. In the 1990s, renewed interest came from a concern for the environment in response to scientific studies indicating potential changes to the global climate if the use of fossil fuels continues to increase.

This situation, termed global warming, has gained the attention of many Americans recently and increased the desire to develop economical alternative energy sources. Wind energy offers a viable, economical alternative to conventional power plants in many areas of the country.

Wind is a clean fuel — wind power plants produce no air or water pollution because no fuel is burned. Also, the cost of producing electricity from the wind has dropped dramatically in the last 20 years. Electricity generated by wind cost 30 cents per kWh in 1975, but now costs less than five cents per kWh.

New turbines are lowering the cost even more. The most serious environmental drawbacks to wind machines may be their negative effect on wild bird populations and the visual impact on the landscape.

Renewable energy sources:

(a) Wind turbines at Tehachapi Pass, California. This wind farm, with 5,000 wind turbines, is the second largest collection of wind generators in the world. The turbines produce enough electricity to meet the needs of 350,000 people every year.

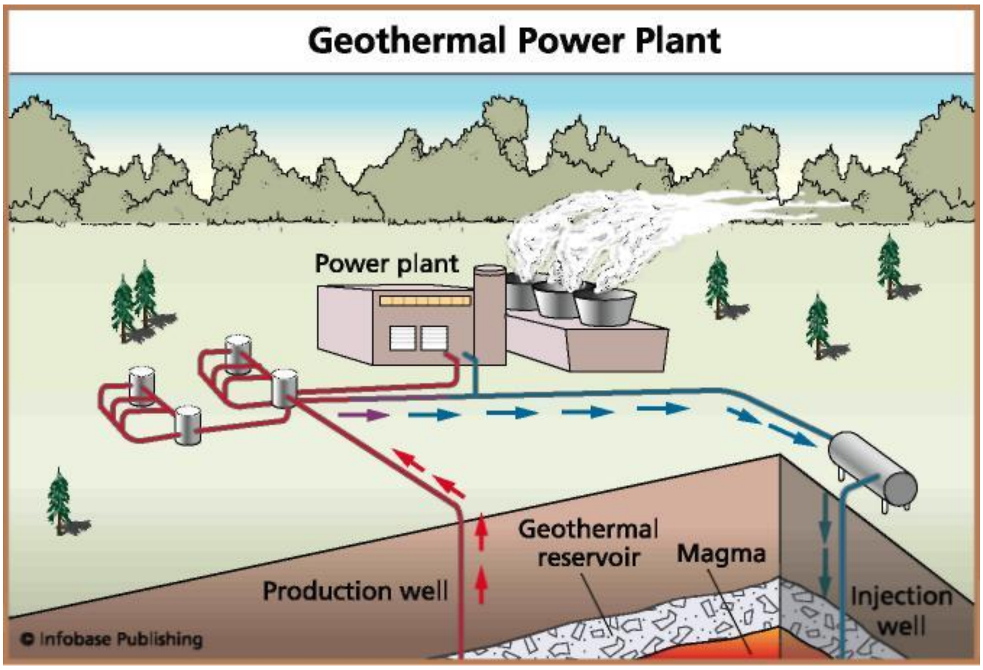
(b) Vertical axis wind turbines located in Altamont Pass in California.

(c) Offshore wind turbine and photovoltaic system, which powers a U.S. Navy offshore test facility.

(d) Geysers are natural fountains of hot water found in geothermal areas.

(e) This solar energy-collecting unit is located at the California State Polytechnic University.

(a, b, c, e, courtesy of U.S. Department of Energy; d, courtesy of U.S. National Renewable Energy Laboratory, photo by George Kourkouliotis)



Components of a geothermal power plant

Geothermal Energy

Volcanic energy cannot be harnessed (controlled and collected), but in a few places, heat from the Earth — called geothermal energy — can be collected. Usually, engineers try to collect this heat in the rare places where the Earth's crust has trapped steam and hot water. At these locations, they drill into the crust and allow the heat to escape, either as steam or as very hot water. Pipes carry the hot water to a plant, where some of the steam is allowed to "flash," or separate from the water. That steam then turns a turbine generator to make electricity.

Geothermal energy was first used to produce electricity in Italy in 1903. At the end of 2002, there were 43 power plants producing electricity from geothermal energy in the United States at facilities located in California, Nevada, Utah, and Hawaii. Generation from geothermal sources is "site specific," meaning it is only possible in a few places under unique geologic conditions. One such site in California, called The Geysers, is able produce almost as much electricity as all the other geothermal sites combined.

Geothermal energy can be used as an efficient heat source in small end-use applications such as greenhouses, but the consumers have to be located close to the source of heat. The capital of Iceland — Reykjavik — is a unique location because it is heated mostly by geothermal energy.

Geothermal energy has a major environmental benefit because it offsets air pollution that would have been produced if fossil fuels had been used instead. Geothermal energy has a very minor impact on the soil — the few acres used look like a small light-industry building complex. Since the slightly cooler water is reinjected into the ground, there is only a minor impact, except if there is a natural geyser field close by. For this reason, tapping into the geothermal resources of Yellowstone National Park is prohibited by law.

Biomass — Renewable Energy From Plants and Animals

Biomass is organic material made from plants and animals. Biomass contains stored energy from the sun. Plants absorb the sun's energy in a process called photosynthesis. The chemical energy in plants gets passed in the food chain on to the animals and people that eat them. Biomass is a renewable energy source because it is possible to grow more trees and crops. Some examples of biomass fuels are wood, crops, manure, and some garbage.

When burned, the chemical energy in biomass is released as heat. An example of this is wood burning in a fireplace. Wood waste or garbage can be burned to produce steam for making electricity or to provide heat to industries and homes.

Burning biomass is not the only way to release its energy. Biomass can be converted to other usable forms of energy like methane gas or transportation fuels like ethanol and biodiesel. Methane gas is the main ingredient of natural gas. Rotting garbage, agricultural waste, and human waste, release methane gas — also called "landfill gas" or "biogas." Crops like corn and sugarcane can be fermented to produce the transportation fuel ethanol. Biodiesel, another transportation fuel, can be produced from leftover food products like vegetable oils and animal fats.

According to the U.S. Department of Energy, biomass fuels provide about 3% of the energy used in the United States, as efforts are underway to develop ways to burn more biomass and less fossil fuels. Using biomass for energy can cut back on waste and support agricultural products grown in the United States. Biomass fuels also have a number of environmental benefits.

The most common form of biomass is wood. For thousands of years, people have burned wood for heating and cooking. Wood was the main source of energy in the United States and the rest of the world until the mid-1800s. In the United States, wood and its waste products (bark, sawdust, wood chips, and wood scrap) provide only about 2% of the energy used today. Biomass continues to be a major source of energy in much of the developing world.

According to data from the U.S. Department of Energy, only 20% of the wood burned in the United States is used for heating and cooking; the rest is used by industries in the manufacture of several commodities, such as paper products and construction materials, as well as to produce the electricity needed in the manufacturing process. Such use by industry presents an efficient way for industries to recycle the waste byproducts generated from the wood they use into energy.

Another source of biomass is garbage — also called municipal solid waste (MSW). Trash that comes from plant or animal products is biomass. Food scraps, lawn clippings, and leaves are all examples of biomass trash. Materials that are made out of glass, plastic, and metals are not biomass because they are made out of nonrenewable materials.

MSW can be a source of energy by either burning MSW in waste-to-energy plants or by capturing biogas. In waste-to-energy plants, trash is burned to produce steam that can be used either to heat buildings or to generate electricity. In landfills, biomass rots and releases methane gas, also called biogas, or landfill gas. Some landfills have a system that collects the methane gas so that it can be used as a fuel source. Some dairy farmers collect biogas in tanks called digesters, where they put all the mulch and manure from their barns.

Biofuels are transportation fuels like ethanol and biodiesel that are made from biomass materials. These fuels are usually blended with the petroleum fuels — gasoline and diesel — but they can also be used on their own.

The advantage to combining ethanol or biodiesel with fossil fuel is that less fossil fuels are burned resulting in less of an impact on global warming. Ethanol and biodiesel are usually more expensive than the fossil fuels that they replace, but they are also cleaner burning fuels, producing fewer air pollutants.

Ethanol is an alcohol fuel made from the sugars found in grains, such as corn, sorghum, and wheat, as well as potato skins, rice, sugarcane, sugar beets, and yard clippings. Scientists are working on cheaper ways to make ethanol by using all parts of plants and trees.

Farmers are experimenting with “woody crops” — mostly small poplar trees and switchgrass — to see if they can be grown efficiently. Most of the ethanol used in the United States today is distilled from corn.

About 90% of the ethanol produced in the United States is used to make “E10” or “gasohol,” a mixture of 10% ethanol and 90% gasoline. Any gasoline-powered engine can use E10, but only specially made vehicles can run on E85, a fuel that is 85% ethanol and 15% gasoline.

Biodiesel is a fuel made with vegetable oils, fats, or greases—such as recycled restaurant grease. These fuels can be used in diesel engines. Biodiesels are the fastest growing alternative fuel in the United States today.

Being a renewable fuel, biodiesel is safe, biodegradable, and reduces the emissions of most air pollutants. Burning biomass fuels does not produce pollutants like sulfur, which can cause acid rain.

When burned, biomass does release carbon dioxide — a greenhouse gas. But when biomass crops are grown, a nearly equivalent amount of carbon dioxide is captured through the process of photosynthesis. Each of the different forms and uses of biomass impact the environment in a different way.

Because the smoke from burning wood contains pollutants like carbon monoxide and particulate matter, some areas of the country will not allow the use of wood-burning fireplaces or stoves on high pollution days. A special clean-burning technology can be added to wood-burning fireplaces and stoves so that they can be used even on days with the worst pollution.

Burning municipal solid waste (MSW or garbage) and wood waste to produce energy means that less of it has to be buried in landfills. Plants that burn waste to make electricity must use technology to prevent harmful gases and particles from coming out of their smokestacks. The particles that are filtered out are added to the ash that is removed from the bottom of the furnace. Because the ash may contain harmful chemicals and metals, it must be disposed of carefully. Sometimes the ash can be used for road-work or building purposes.

Collecting and using landfill waste and biogas fuel also reduces the amount of methane that is released into the air. Methane is one of the greenhouse gases associated with global climate change. Many landfills find it cheaper to just burn off the gas that they collect, however, because the gas needs to be processed before it can be put into natural gas pipelines.

Since the early 1990s, ethanol has been blended into gasoline to reduce harmful carbon monoxide emissions. Blending ethanol into gasoline also reduces toxic pollutants found in gasoline but causes more “evaporative emissions” to escape.

In order to reduce evaporative emissions, the gasoline requires extra processing before it can be blended with ethanol. When burned, ethanol does release carbon dioxide, a greenhouse gas. But growing plants for ethanol may reduce greenhouse gases, since plants use carbon dioxide and produce oxygen as they grow — producing a counter-balance process.

Biodiesel is much less polluting that petroleum diesel. It has lower emissions of carbon dioxide, sulfur oxide, particulates, carbon monoxide, air toxins, and unburned hydrocarbons, although it does have slightly elevated emissions of nitrogen oxide. Biodiesel additives can also help reduce sulfur in diesel fuel.

Ocean Energy

Oceans cover more than 70% of the Earth’s surface. As the world’s largest solar collectors, oceans generate thermal energy from the Sun. They also produce mechanical energy from the tides and waves. Even though the Sun affects all ocean activity, the gravitational pull of the Moon primarily drives the tides, while the wind powers the ocean waves.

For the past thousand years, scientists and inventors have studied ocean energy as they have watched how the ocean waves impact with coastal areas and observed the rise and fall of ocean tides. As early as the eleventh century, millers in Britain figured out how to use tidal power to grind their grain into flour. Only in the past 100 years, however, have scientists and engineers begun to look at capturing ocean energy to actually produce electricity.

Because ocean energy is abundant and non-polluting, today’s researchers are exploring ways to make ocean energy economically competitive with fossil fuels and nuclear energy. European Union (EU) officials estimate that by 2010, ocean energy sources will generate more than 950 **megawatts** (MW) of electricity — enough to power almost a million homes in the industrialized world.

The tides produce energy. Tides are caused by the gravitational pull of the Moon and Sun and the rotation of the Earth. Near shore, water levels can vary up to 40 feet (12 m). However, few locations have good inlets and a large enough tidal range—about 10 feet (3 m)—to produce energy economically.

The simplest generation system for tidal plants involves a dam, known as a barrage, built across an inlet. Sluice gates on the barrage allow the tidal basin to fill on the incoming high tides and to empty through the turbine system on the outgoing tide, which is also known as the ebb tide.

There are also two-way systems that generate electricity on both the incoming and outgoing tides. Tidal barrages can affect navigation and recreation, however. Potentially the largest disadvantage of tidal power is the effect a tidal station can have on plants and animals in the estuaries.

Tidal fences can also harness the energy of tides. A tidal fence has vertical-axis turbines mounted in it. The water is forced through the turbines as it passes through the fence. They can be used in areas such as channels between two landmasses. Tidal fences have less impact on the environment than tidal barrages, but they can still disrupt the movement of large marine animals. They are also cheaper to install than tidal barrages.

Tidal turbines are a new technology that can be used in many tidal areas. They are basically wind turbines that can be located anywhere there is strong enough tidal flow. Because water is about 800 times denser than air, tidal turbines have to be much sturdier than wind turbines. This makes them more expensive to build, but they have the advantage of being able to capture more energy.

There is also a lot of energy in ocean waves. According to the U.S. Department of Energy, the total power of waves breaking around the world's coastlines is estimated at 2–3 million megawatts. The west coasts of the United States and Europe, and the coasts of Japan and New Zealand, are desirable sites for harnessing wave energy.

One way to harness wave energy is to bend the waves into a narrow channel, thereby increasing their power and size. The waves can then be channeled into a catch basin or used directly to spin turbines. There are no big commercial wave energy plants yet, but there are a few small ones. Scientists at the Department of Energy believe that small, onshore sites have the best potential for the immediate future — they could produce enough energy to power local communities.

The energy from the sun heats the surface water of the ocean. In tropical regions, the surface water can be 40 or more degrees warmer than the deep water. This temperature difference can also be used to produce electricity.

One system — called the Ocean Thermal Energy Conversion (OTEC) — must have a temperature difference of at least 77°F (25°C) to operate, which limits its use to tropical regions. (Hawaii is a case in point. They have experimented with OTEC since the 1970s.)

There is no large-scale operation of OTEC today, because there are still many challenges to overcome. First, the OTEC systems are not very energy efficient. Pumping water is a significant engineering challenge itself.

There must also be a method in place to transport the generated electricity to land. Experts at the U.S. Department of Energy believe it will probably be 10 to 20 years before the technology is available to produce and transmit electricity economically from the OTEC systems. Other types of research are being done to place solar farms over the ocean. Many experts believe the ideal place for solar farms is near the coasts, because they would be less cumbersome to build and be able to be accessed easier. Currently, solar energy is used on offshore platforms and also to operate remotely located equipment at sea. Solar energy is attractive as a potential energy source because it is renewable, it is free, and it does not pollute the environment.

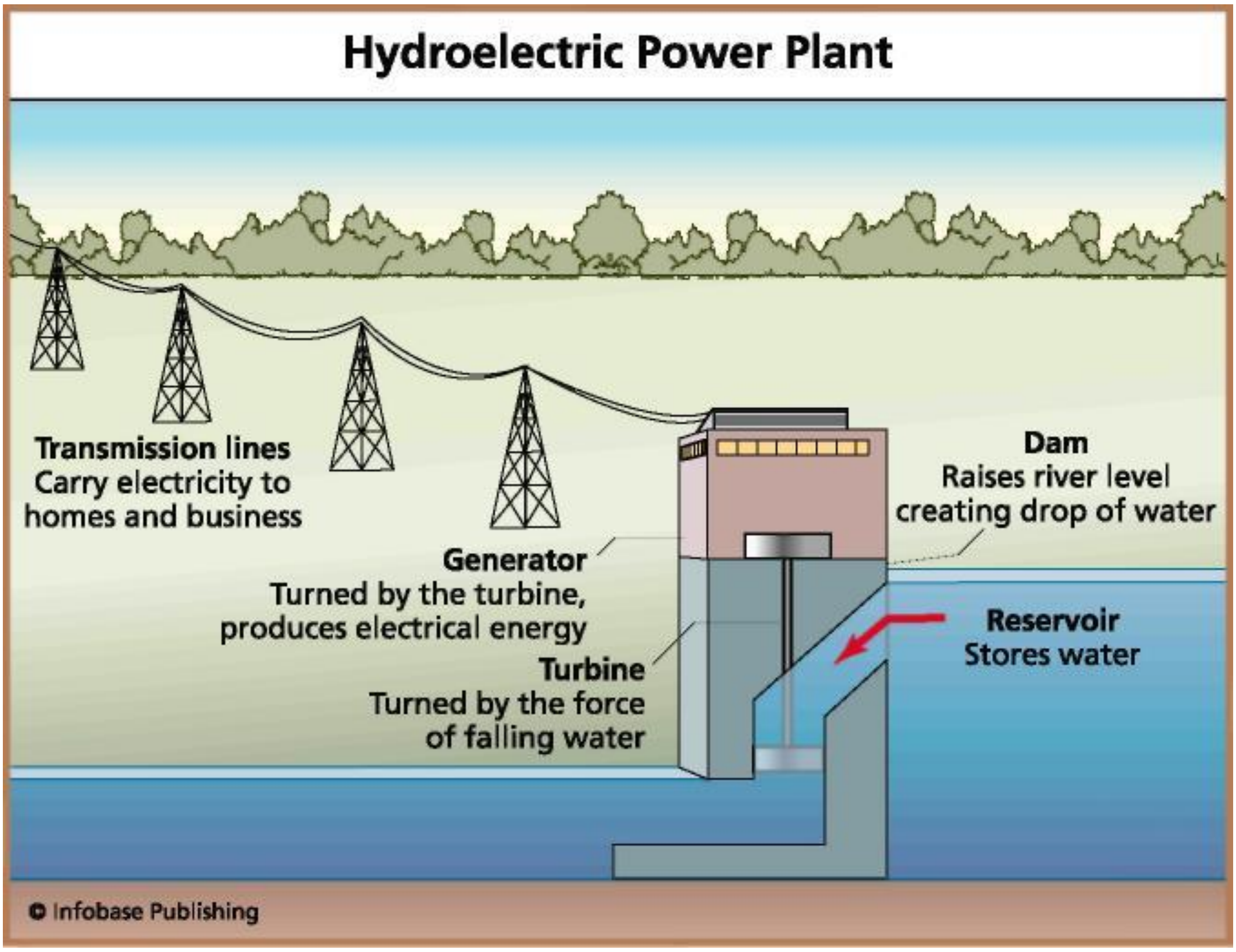
Wind energy, like solar energy, is already used on land. As mentioned earlier, wind turbines and wind power plants can only be placed in specific areas where the wind constantly blows. Along the coast of much of the United States, conditions are favorable toward the use of wind energy. (There are people, however, who are opposed to putting turbines just offshore, because they believe it will spoil the ocean view.) Currently, there is a plan to build an offshore wind plant off the coast of Cape Cod, Maryland. Wind is a renewable energy source that does not pollute; so many people see it as a good alternative to fossil fuels.

Hydroelectric Power

Of the renewable energy sources that generate electricity, hydropower is the most often used. It accounted for 7% of U.S. generation and 45% of renewable generation in 2003 (according to U.S. Department of Energy studies).

Hydropower is one of the oldest sources of energy. For example, as we saw earlier, it was used thousands of years ago to turn paddle wheels, which were used to grind grain. The first industrial use of hydropower in the United States to generate electricity happened in 1880 in Grand Rapids, Michigan.

The first U.S. hydroelectric power plant opened on the Fox River near Appleton, Wisconsin, on September 30, 1882. Up until that time, coal was the only fuel used to produce electricity. Because the source of hydropower is water, hydroelectric power plants must be located on a water source. Therefore, it wasn't until the technology to transmit electricity over long distances via transmission lines was developed that hydropower became widely used.



Schematic of a hydroelectric power plant.

Directing, harnessing, or channeling moving water drives mechanical energy. The amount of available energy in moving water is determined by the rate at which it flows or falls. Swiftly flowing water in a big river carries a great deal of energy in its flow. Similarly, water descending rapidly from a very high point also carries a great deal of energy as it falls.

The water flows through a pipe — also called a pen-stock — and then pushes against and turns the blades in a turbine to spin a generator in order to produce electricity. In a "run-of-the-river" system, the force of the current applies the needed pressure, while in a storage system, water is accumulated in reservoirs created by dams and then released when the demand for electricity is high. Meanwhile, the reservoirs or lakes are used for boating and fishing, and often the rivers beyond the dams provide opportunities for white-water rafting and kayaking.

The U.S. Department of Energy has determined that 56% of the total U.S. hydroelectric capacity for electricity generation is concentrated in three states: Washington, California, and Oregon. Only a small percentage of all dams in the United States produce electricity. Most other U.S. dams were constructed mainly to provide irrigation and flood control.

Hydropower is an ideal fuel for electricity generation because, unlike the nonrenewable fuels used to generate electricity, it is almost free, there are no waste products, and it does not pollute the water or the air.

It is sometimes criticized, however, because it does change the environment by affecting natural habitats. For example, in the Columbia River in Washington, salmon must swim upstream to their spawning grounds to reproduce, but the series of dams gets in their way. Different approaches to fixing this problem have been used, including the construction of "fish ladders" that help the salmon "step up" the dam to the spawning grounds upstream.

As the world's energy demand increases, fossil fuels become less accessible, and people learn more about the benefits to health and life of maintaining a clean environment, the renewable resources covered in this chapter will become increasingly important.

IRREGULAR VERBS

Infinitive		Past Tense		Past Participle		Переклад
arise	[ə'raiz]	**arose**	[ə'rəuz]	**arisen**	[ə'riz(ə)n]	виникати, з'являтися
awake	[ə'weik]	**awoke**	[ə'wəuk]	**awoken**	[ə'wəukən]	будити, пробуджуватися
be	[bi:]	**was,were**	[wɔz],[wɜ:]	**been**	[bi:n]	бути
bear	[bɛə]	**bore**	[bɔ:]	**born**	[bɔ:n]	народжувати, приносити
beat	[bi:t]	**beat**	[bi:t]	**beaten**	['bi:tn]	бити
become	[bɪ 'kʌm]	**became**	[bɪ 'keɪm]	**become**	[bɪ 'kʌm]	ставати
begin	[bɪ 'gɪn]	**began**	[bɪ 'gæn]	**begun**	[bɪ 'gʌn]	починати(ся)
bend	[bend]	**bent**	[bent]	**bent**	[bent]	гнути, згинати
bind	[baɪnd]	**bound**	[baʊnd]	**bound**	[baʊnd]	пов'язувати
bite	[baɪt]	**bit**	[bɪt]	**bitten**	['bɪtn]	кусати(ся)
bleed	[bli:d]	**bled**	[bled]	**bled**	[bled]	кровоточити
blow	[blou]	**blew**	[blu:]	**blown**	[bloun]	дути
break	[breɪk]	**broke**	[brouk]	**broken**	['broukən]	ламати(ся)
breed	[bri:d]	**bred**	[bred]	**bred**	[bred]	виховувати
bring	[brɪŋ]	**brought**	[brɔ:t]	**brought**	[brɔ:t]	приносити
build	[bɪld]	**built**	[bɪlt]	**built**	[bɪlt]	будувати
burn	[bɜ:rn]	**burnt**	[bɜ:nt]	**burnt**	[bɜ:nt]	горіти, палити
burst	[bɜ:st]	**burst**	[bɜ:st]	**burst**	[bɜ:st]	вибухнути, підривати
buy	[baɪ]	**bought**	[bɔ:t]	**bought**	[bɔ:t]	купувати
cast	[kα:st]	**cast**	[kα:st]	**cast**	[kα:st]	кинути, лити (метал)
catch	[kætʃ]	**caught**	[kɔ:t]	**caught**	[kɔ:t]	ловити, схоплювати
choose	[tʃu:z]	**chose**	[tʃouz]	**chosen**	['tʃouzən]	вибирати, підбирати
come	[kʌm]	**came**	[keɪm]	**come**	[kʌm]	приходити
cost	[kɒst]	**cost**	[kɒst]	**cost**	[kɒst]	коштувати
cut	[kʌt]	**cut**	[kʌt]	**cut**	[kʌt]	різати
dig	[dɪg]	**dug**	[dʌg]	**dug**	[dʌg]	рити, копати
do	[du:]	**did**	[dɪd]	**done**	[dʌn]	робити
draw	[drɔ:]	**drew**	[dru:]	**drawn**	[drɔ:n]	малювати, тягти
dream	[dri:m]	**dreamt**	[dremt]	**dreamt**	[dremt]	мріяти, снитися
drink	[drɪŋk]	**drank**	[dræŋk]	**drunk**	[drʌŋk]	пити
drive	[draɪv]	**drove**	[drouv]	**driven**	['drɪvən]	водити

Infinitive		Past Tense		Past Participle		Переклад
eat	[i:t]	**ate**	[eɪt, et]	**eaten**	['i:tn]	їсти
fall	[fɔ:l]	**fell**	[fel]	**fallen**	['fɔ:lən]	падати
feed	[fi:d]	**fed**	[fed]	**fed**	[fed]	годувати
feel	[fi:l]	**felt**	[felt]	**felt**	[felt]	відчувати
fight	[faɪt]	**fought**	[fɔ:t]	**fought**	[fɔ:t]	боротися
find	[faɪnd]	**found**	[faʊnd]	**found**	[faʊnd]	знаходити
fit	[fit]	**fit**	[fit]	**fit**	[fit]	підходити за розміром
fly	[flaɪ]	**flew**	[flu:]	**flown**	[floun]	літати
forget	[fər'get]	**forgot**	[fər'gɒt]	**forgotten**	[fər'gɒtn]	забувати
forgive	[fər'gɪv]	**forgave**	[fər'geɪv]	**forgiven**	[fər'gɪvən]	пробачати
freeze	[fri:z]	**froze**	[frouz]	**frozen**	['frouzən]	замерзати
get	[get]	**got**	[gɒt]	**got**	[gɒt]	отримувати
give	[gɪv]	**gave**	[geɪv]	**given**	['gɪvən]	давати
go	[gou]	**went**	[went]	**gone**	[gɒn]	іти, ходити
grow	[grou]	**grew**	[gru:]	**grown**	[groun]	рости
hang	[hæŋ]	**hung**	[hʌŋ]	**hung**	[hʌŋ]	висіти, розвішувати
have	[hæv]	**had**	[hæd]	**had**	[hæd]	мати
hear	[hɪər]	**heard**	[hɜ:rd]	**heard**	[hɜ:rd]	чути
hide	[haɪd]	**hid**	[hɪd]	**hidden**	['hɪdn]	ховати
hit	[hɪt]	**hit**	[hɪt]	**hit**	[hɪt]	потрапляти в ціль
hold	[hould]	**held**	[held]	**held**	[held]	тримати
hurt	[hɜ:rt]	**hurt**	[hɜ:rt]	**hurt**	[hɜ:rt]	поранити, пошкодити
keep	[ki:p]	**kept**	[kept]	**kept**	[kept]	тримати, зберігати
kneel	[ni:l]	**knelt**	[nelt]	**knelt**	[nelt]	ставати на коліна
knit	[nɪt]	**knit**	[nɪt]	**knit**	[nɪt]	в'язати (спицями)
know	[nou]	**knew**	[nu:]	**known**	[noun]	знати
lay	[leɪ]	**laid**	[leɪd]	**laid**	[leɪd]	класти, покласти
lead	[li:d]	**led**	[led]	**led**	[led]	вести, очолювати
lean	[li:n]	**leant**	[lent]	**leant**	[lent]	нахилятися
learn	[lɜ:rn]	**learnt**	[lɜ:rnt]	**learnt**	[lɜ:rnt]	вчити
leave	[li:v]	**left**	[left]	**left**	[left]	залишати, покидати
lend	[lend]	**lent**	[lent]	**lent**	[lent]	займати, позичати

Infinitive		Past Tense		Past Participle		Переклад
let	[let]	**let**	[let]	**let**	[let]	дозволяти
lie	[laɪ]	**lay**	[leɪ]	**lain**	[leɪn]	лежати
light	[lait]	**lit**	[lit]	**lit**	[lit]	висвітлювати, запалювати
lose	[lu:z]	**lost**	[lɒst]	**lost**	[lɒst]	втрачати
make	[meɪk]	**made**	[meɪd]	**made**	[meɪd]	робити
mean	[mi:n]	**meant**	[ment]	**meant**	[ment]	значити
meet	[mi:t]	**met**	[met]	**met**	[met]	зустрічати
mistake	[mis'teik]	**mistook**	[mis'tuk]	**mistaken**	[mis'teik(e)n]	помилятися
pay	[peɪ]	**paid**	[peɪd]	**paid**	[peɪd]	платити
put	[pʊt]	**put**	[pʊt]	**put**	[pʊt]	класти, ставити
read	[ri:d]	**read**	[red]	**read**	[red]	читати
ride	[raɪd]	**rode**	[roud]	**ridden**	['rɪdn]	їхати верхи
ring	[rɪŋ]	**rang**	[ræŋ]	**rung**	[rʌŋ]	дзвонити, дзвеніти
rise	[raɪz]	**rose**	[rouz]	**risen**	['rɪzən]	підніматися
run	[rʌn]	**ran**	[ræn]	**run**	[rʌn]	бігти
say	[seɪ]	**said**	[sed]	**said**	[sed]	говорити
see	[si:]	**saw**	[sɔ:]	**seen**	[si:n]	бачити
seek	[si:k]	**sought**	[sɔ:t]	**sought**	[sɔ:t]	шукати
sell	[sel]	**sold**	[sould]	**sold**	[sould]	продавати
send	[send]	**sent**	[sent]	**sent**	[sent]	посилати
set	[set]	**set**	[set]	**set**	[set]	класти, ставити
shake	[ʃeɪk]	**shook**	[ʃʊk]	**shaken**	['ʃeɪkən]	трясти
shine	[ʃaɪn]	**shone**	[ʃoun, ʃɒn]	**shone**	[ʃoun, ʃɒn]	світити, сяяти, блищати
shoot	[ʃu:t]	**shot**	[ʃɒt]	**shot**	[ʃɒt]	стріляти
show	[ʃou]	**showed**	[ʃoud]	**shown**	[ʃoun]	показувати
shrink	[ʃriŋk]	**shrank**	[ʃræŋk]	**shrunk**	[ʃrʌŋk]	сідати (про матеріал), зменшувати(ся), скорочувати(ся)
shut	[ʃʌt]	**shut**	[ʃʌt]	**shut**	[ʃʌt]	закривати
sing	[sɪŋ]	**sang**	[sæŋ]	**sung**	[sʌŋ]	співати
sink	[sɪŋk]	**sank**	[sæŋk]	**sunk**	[sʌŋk]	тонути
sit	[sɪt]	**sat**	[sæt]	**sat**	[sæt]	сидіти

Infinitive		Past Tense		Past Participle		Переклад
sleep	[sli:p]	**slept**	[slept]	**slept**	[slept]	спати
smell	[smel]	**smelt**	[smelt]	**smelt**	[smelt]	нюхати, пахнути
slide	[slaid]	**slid**	[slid]	**slid**	[slid]	ковзати
sow	[sou]	**sowed**	[soud]	**sown**	[soun]	сіяти, засівати
smell	[smel]	**smelled**	[smeld]	**smelled**	[smeld]	нюхати, пахнути
speak	[spi:k]	**spoke**	[spouk]	**spoken**	['spoukən]	говорити
spell	[spel]	**spelt**	[spelt]	**spelt**	[spelt]	вимовляти по буквах
spend	[spend]	**spent**	[spent]	**spent**	[spent]	витрачати
spill	[spɪl]	**spilt**	[spɪlt]	**spilt**	[spɪlt]	проливати
spit	[spɪt]	**spat**	[spæt]	**spat**	[spæt]	плювати
split	[splɪt]	**split**	[splɪt]	**split**	[splɪt]	розщеплювати
spoil	[spoɪl]	**spoilt**	[spoɪlt]	**spoilt**	[spoɪlt]	псувати
spread	[spred]	**spread**	[spred]	**spread**	[spred]	поширювати(ся)
stand	[stænd]	**stood**	[stʊd]	**stood**	[stʊd]	стояти
steal	[sti:l]	**stole**	[stoul]	**stolen**	['stoulən]	красти
stick	[stik]	**stuck**	[stʌk]	**stuck**	[stʌk]	приклеювати(ся), застрявати, упиратися
sting	[stiŋ]	**stung**	[stʌŋ]	**stung**	[stʌŋ]	жалити
strike	[straɪk]	**struck**	[strʌk]	**struck**	[strʌk]	ударяти, страйкувати
strive	[straɪv]	**strove**	[strəuv]	**striven**	['strɪvn]	намагатися, прагнути
swear	[sweə]	**swore**	[swɔ:]	**sworn**	[swɔ:n]	давати клятву
sweep	[swi:p]	**swept**	[swept]	**swept**	[swept]	помсти, підмітати
swim	[swɪm]	**swam**	[swæm]	**swum**	[swʌm]	плавати
take	[teɪk]	**took**	[tʊk]	**taken**	['teɪkən]	брати, взяти
teach	[ti:tʃ]	**taught**	[tɔ:t]	**taught**	[tɔ:t]	вчити
tear	[teər]	**tore**	[tɔr]	**torn**	[tɔrn]	рвати
tell	[tel]	**told**	[tould]	**told**	[tould]	розповідати
think	[θɪŋk]	**thought**	[θɔ:t]	**thought**	[θɔ:t]	думати
throw	[θrou]	**threw**	[θru:]	**thrown**	[θroun]	кидати
understand	[ʌndər 'stænd]	**understood**	[ʌndər 'stʊd]	**understood**	[ʌndər 'stʊd]	розуміти
upset	[ʌp'set]	**upset**	[ʌp'set]	**upset**	[ʌp'set]	перекидати, засмучувати (плани), засмучувати
wake	[weɪk]	**woke**	[wouk]	**woken**	['woukən]	прокидатися

Infinitive		Past Tense		Past Participle		Переклад
wear	[weər]	**wore**	[wɔr]	**worn**	[wɔrn]	носити
weep	[wi:p]	**wept**	[wept]	**wept**	[wept]	плакати
wet	[wet]	**wet**	[wet]	**wet**	[wet]	мочити, зволожувати
win	[wɪn]	**won**	[wʌn]	**won**	[wʌn]	вигравати, перемагати
wind	[waind]	**wound**	[waund]	**wound**	[waund]	звиватися, обмотувати, заводити (годинник)
write	[raɪt]	**wrote**	[rout]	**written**	['rɪtn]	писати

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