

AN INTRODUCTION

Energy has been with us since time began, even before the first ray of light shone down on the proto-planet that was to become Earth. In fact, light is in itself a form of energy.

Without it - ENERGY - we would not exist...

Without it, we would never have evolved and developed to the place we hold on this planet in which we today find ourselves. But what place, what position is that? The answer is the basis of this book.

I do not presume to present myself as an expert on any of the topics herein. There are those who have much higher claim to that title. However, I have been involved in the energy industry for more than thirty five years in one way or the other and it is that experience and accumulation of knowledge I hope to share with you.

Although subdivided into chapters, this book is broken down into three basic sections:

- **How we got here**
- **What we are doing here**
- **Where we go from here**

The primary source of all energy, for our small planet at least, is the Sun. The known universe is full of suns, but our Sun is the only one close enough to provide sufficient energy to allow Earth to have developed as it has.

But what is energy? Put one way, energy is the single most important technological challenge facing humanity today. Nothing else in science or technology comes close in comparison according to Professor of Chemistry at Caltech, Nate Lewis PhD (MIT).

Or, put as simply as possible, energy is a 'store', a repository of an ability to do work. You cannot 'see' energy, it is a concept. What you see are manifestations of energy transfer, energy conversion or the energy 'store'. When someone says they are awed by the 'raw energy' of a raging sea, what they really are witnessing is the expenditure of the energy that drives the system, into something else. Similarly, a battery is not 'energy', it is an energy 'store' - it has the 'potential' to provide energy, given the right conditions.

Energy, by definition, now amply supported by experiment, cannot be destroyed. It can only be converted into some other form of energy. Anyone driving a powerful, gas-guzzling six or eight cylinder-engined car would probably beg to differ, but in fact that is only because they have not taken into consideration the total dispersion of the energy inherent in their litre of gasoline.

That litre of gasoline will release a certain amount of energy, energy that is inherent in the bonding of the atoms that constitute the liquid. Imagine if you took a litre of gasoline and sealed it into a solidly built container, provide oxygen and an ignition source and watched what happens. There would be an explosion sufficient to take the windows out of every building in the vicinity. This is because the litre of gasoline has been converted into other forms of energy - light, sound, heat, etc.

Basically the same thing is happening within your car engine cylinder - light, sound, heat. The light is wasted energy, it has nowhere to go. The sound is also wasted energy. In fact, most cars now have insulation around the engine compartment to try to muffle the sound, as it is more annoying than useful. The only time you are likely to hear it is when your engine misfires and you get a loud 'backfire' sound.

So, out of your litre of gasoline, all you have acquired that is useful is heat. This heat expands the gases created, driving the cylinder downwards,

which in turn rotates a crank, converting heat into rotation, which is eventually converted into distance, as your car moves.

Some of this may be Double Dutch to you, but please bear with me, all will be explained, eventually. What I'm endeavouring to do right now is to show how we have learned how to waste energy.

You have converted liquid (chemical) energy - petroleum, or gasoline - into distance. But at what cost? So far we have 'lost' energy to sound and light. The heat generated, while used to expand the gases in the cylinders of your engine, also heats up the engine block, which would eventually burn up (as anyone who has run out of water in their engine radiator will know). This heat is eventually vented into the atmosphere through your engine's radiator.

An internal combustion engine is in fact an extremely poor converter of energy. A figure of about 25% efficiency is considered average for a well-maintained engine. This means that 75% of the energy contained in that litre of gasoline goes out the window! Or rather, up the exhaust pipe. And that's in a well-maintained engine! How much less efficient are the rest of the vehicles on the road today?

The above was not, is not, intended to be a lesson on the internal combustion engine, nor is it a lesson on energy conversion. The sole intention is to, I hope, highlight how inefficient in many ways is our technology and how much we have wasted. Only now, are we beginning to investigate this wastage and the effects it is having on our environment.

Anyway, back to our energy quest. Energy, as stated above, cannot be destroyed, only converted from one form to another. A simple illustration would be to lift a normal, red clay, kiln-fired building brick up on top of a wall. That brick now has what is called potential energy, i.e., a potential to supply energy by virtue of its position - on top of the wall. But, it took energy to get that brick up there in the first place, didn't it?

Where did that energy come from?

In a roundabout way, it came from the Sun. You expended energy in lifting the brick up onto the wall, in this case the chemical energy of your body (glucose), which you converted into mechanical energy through your muscles. That glucose energy in turn came from the food you eat, which was itself, in turn, 'energised' by the Sun during its growth.

Fairly simple so far, isn't it?

Something a bit more complicated however, is the equation, $E = mc^2$, where E equals energy, m is the mass of the material in question and c is the speed of light in a vacuum, an equation proposed by Albert Einstein in the earlier part of the 20th century but only proven, with the detonation of a device at the Trinity Site at Alamogordo in New Mexico many years thereafter - the 'Atom' bomb. Since E = energy (in electron volts), just think of the quantity released by the detonation of an atomic bomb, where m = mass (in kg) and c = the speed of light in a vacuum – 300,000,000 m/sec.

Mass, (anything having weight), could be changed into energy!

Man finally found an alternative to the Sun in energy production. Even so, the Sun did have a lot to do with it. Our Sun, or at least its kind, had everything to do with it actually, but not the subject of this present argument, which is the transformation of energy from one type to another. We will come back to atomic, or nuclear energy later.

Energy comes in many different forms, but four types will suffice for most arguments. Remember, energy is the 'potential' to do work. The brick on top of the wall has potential energy, as does water in a reservoir, poised above a turbine generator. The litre of gasoline has energy, this time it is chemical energy, inherent in the bonds of the atoms and molecules of which it is made (explained later).

Kinetic energy, (from the Greek *kinetikos* - move) is the energy inherent in an object by virtue of its movement. Imagine a hammer descending

rapidly towards a nail head. The hammer possesses 'kinetic' energy. (So does a car travelling at 150 km/hr down the expressway. Lots of it).

The fourth type of energy of interest to us in this book is nuclear energy. Science divides energy up into many other recognised forms, internal, heat, light, etc., but the main four mentioned are forms from which most others are derived.

For millennia, Mankind was satisfied with the most primitive of energy sources - fire - a natural phenomenon he learned to control and master. This fire, he made by burning flammable material - grasses, wood bark, twigs and fallen branches. He used fire primarily for light - it scared away animals - and heat, allowing him to move further north on the global continental landmass. Only later did he find out that cooked meat tasted better than raw, using the fire to roast animals he had slaughtered (and thereby laying the groundwork for one of the most dreadful diseases to which Man in particular is prone – stomach cancer – caused by the energetic alteration of protein into cancer-causing agents, i.e., burning it!)

However, the stuff that dreams are made of, and wars fought over, the stuff that drove the most rapid expansion of mankind in the history of our time on this planet, arrived on the scene probably millions of years before that, long before Man, except that Man, when he arrived, did not recognise its potential. Not until much later.

Before we go there however, let me digress a moment to define one or two of the more important forms of energy, most notably 'heat'. It is almost inconceivable to think that people are not familiar with heat. You cook your meals using heat. You warm your body using heat. Heat can do a multitude of things that we all find beneficial. But what is heat?

Heat, as we've already decided, is a form of energy. Temperature and heat have only a passing acquaintance although most people consider heat and temperature to be the same thing. A chunk of ice contains less heat than a pan of boiling water, their temperatures vary by a 100 degrees Celsius,

or Centigrade, (180 degrees Fahrenheit) so heat and temperature are synonymous – yes, but not quite. Temperature is a measure of differences in heat content. Differences in heat content are an example of differences in energy content. But then, when energy is continued to be applied to water at its boiling point, it will continue to absorb that energy with no increase in temperature. Similarly, if you continue to extract energy from water at zero degrees Celsius, it will not change in temperature.

The heat absorbed (or extracted) without temperature change is known as latent energy. This is the energy of destroying (or creating) the bonds between the molecules of water, to form steam (or ice). Most people don't know what steam is, because it is not the white fluffy cloud you see coming out of your kettle – that is water droplets made from condensed steam – real steam can be seen (or rather, not seen!) in the very narrow band of clear air at the spout of the kettle. Touching that very narrow band will give you a very severe burn, much worse than if you touch the 'steam' of the white cloud. Any idea why?

The reason is that the clear air section is composed of completely disassociated water molecules. It holds not only the heat of boiling water, but also the heat of breaking the weak bonds between the molecules, the latent heat. The moment it touches your skin, the latent heat is dumped as the water molecules recombine to create water droplets. Of course, your skin absorbs the heat, a lot of it.

All atoms and molecules are in motion. This was first discovered by a Scottish botanist, Robert Brown, around 1827 while inspecting pollen under a microscope. His discovery led to the conclusion that all molecules (and therefore atoms) were in motion – the higher the heat content, the faster the movement. And so it is, throughout the physical world. Everything (everything!) is in motion courtesy of its quality and heat content. Or put another way, heat content is a measure of the state of agitation of the constituent molecules or atoms. Imagine a piece of steel. At room temperature, it is a solid, inflexible piece of metal. Add some heat to it and it will slowly become 'malleable' as in the material of the

sword maker's blade or the blacksmith's horseshoes. Add more heat to it, and it becomes a liquid, which can be shaped and designed according to specially made moulds. Add even more heat to it, and it will become a gas.

Notice the progression? Solid, liquid, gas. Each phase is a step change in energy content, or heat. The more heat applied, the more agitated the molecules or atoms become, first they become plastic, then flowing before finally breaking free from each other as a gas. Each phase change also brings with it an increase in volume – something we will come across frequently as we talk about energy.

A couple of final points before we move on. And this is where temperature comes back into the picture. As mentioned, temperature is a measure of differences between heat content. So, if we draw a graph of temperature vs. heat content for any substance, we end up with a pretty straight line. And this was put to significant use by William Thompson, later Lord Kelvin, when he discovered what became known as zero degrees Kelvin, that point at which there was no heat, therefore no motion – a point at which no material substance can exist. Hydrogen, which becomes a metal when it freezes, does so around 17 degrees Kelvin.

In fact, the freezing, (or boiling) point of each and every atom or molecule is a well defined and known temperature today, and it is used to separate them from each other, especially gases.

The second point is that 'temperature' is not a measure of ALL the heat in a solid, liquid or gas. But more of that later.

On with the quest!

■ How we got here

Hydrocarbons, or fossil fuels*, are the remains of organic material

*'Fossil fuels' is actually a misnomer in the sense that a fossil is the petrified remains of a once living organism, i.e., a chemical replacement process, such as the petrified forests of Arizona USA and Greece, where the soft tissues of plants and trees have been slowly replaced by chemicals to form rock. Hydrocarbons were created by anaerobic decay.

(plankton, etc., in the case of oil and gas; trees and ferns, in the case of coal) and were formed three, four hundred million years ago, during an exceptionally suitable climatic period, warmer than today, when all forms of living material proliferated. The death of these creatures, and plants, their subsequent sedimentation under sometimes kilometres of soil and the heat generated at those depths, in anaerobic conditions, which allowed them to decompose in the absence of oxygen, produced oil, natural gas and coal. Over subsequent centuries, millennia, aeons, some of the liquid and gaseous products of this process migrated back to the surface, through fissures in the rock, through earthquake action, to appear as oil seeps, pockets of asphalt or bitumen, and gas flares.

There are records in ancient scripts referring to the uses Man first made of this unusual material - caulking boats, mummifying bodies, artistic decorations - many things, except as a source of energy! Just imagine how the world might have developed if they had!

Evidence of Man's occupation of the lands between the Mediterranean and the Caspian Seas dates back more than 40,000 years. Known as Mesopotamia, part of the Fertile Crescent, which stretched from the Nile Valley in Egypt to the southern tip of today's Iraq, it lay between the rivers Euphrates and Tigris, and became the home of civilisation.

Here, Man first learned cultivation and the beginnings of a civilised life. In those earliest of times, pools of hydrocarbon liquids were undoubtedly found, and constant fires from gas leaks were a hazard of everyday life. In fact, information from cuneiform tablets, found in the ruins of ancient Babylonian cities, attests to the presence of massive oil and gas induced fires, creating a sense of awe and helplessness in the populace: "...if in a certain place of the land naptu oozes out, that country will walk in widowhood..." and again, "...if a pit opens in fallow land and burning naptu appears, the land will be destroyed..."²

Naptu, is the root of the Arabic word Naft, meaning crude oil and the Greek Nafta, from which we get our English word Naphtha, a principal and important part of the hydrocarbon chain. Again, more later.

By five thousand years ago, this Fertile Crescent area was home to a sophisticated civilisation, with cleverly irrigated fields, domesticated animals and large city-states such as Sumer, Babylon, etc. In these places, hydrocarbon fractions found their way into multiple uses, including oil lamps and for medication, both internal and external. Heavier fractions of the hydrocarbon family were used in a multitude of tasks. Kupru, or bitumen found an ideal use as a waterproofing agent as well as a glue or cement since, by its sticky nature, it stuck to almost everything. It was used in boat building (the basket in which Moses, 3300 years ago, is supposed to have been placed on the Nile was waterproofed with bitumen*), mummification of dead relatives, in art and jewellery - it was even used to make sandals. In fact, evidence exists from archaeological digs that the use of bitumen as a tool, for holding weapons together, dates back as far as 38,000 years ago.

So Man's involvement with hydrocarbons goes back many, many centuries, many millennia, with little evidence that he realised that this was a massive store of energy just waiting to be tapped.[†]

Involvement there was however, in barter and trade and much of the history of the Near East, Egypt, Greece and Rome revolves around this product. It was traded along the Silk Road, both as a glue and as a fuel – they burned lumps of tar. Feuds erupted and city-states were destroyed over the possession of this material, even as they do still today. Except,

*This story is remarkably similar to that of King Sargon of Assyria, recorded 2300 years earlier. (As a follow-on to that, the burning bush that Moses is supposed to have seen, was in all probability a gas vent that caught fire. Just imagine what could have happened if his curiosity rather than his fear had gotten the better of him, and he had discovered the power of hydrocarbon. The Jews would have had the oil instead of the Arabs. This is similar to the Jewish lament that if Moses had only turned right on emerging from the Red Sea, instead of turning left.)

[†]This has to be looked at from the context that around 10,000 years ago, the global population was something like five million. By Anno Domini it was 200 to 300 million and by mid 17th century it was 500 million. In 1800 it was one billion and it only took 130 years for the population of the world to reach two billion. It took 30 years from there to reach three billion; and by 1975 it was four billion; in 11 more years it was five billion. It topped six billion before the end of 1999 and is estimated to reach over nine billion before 2050. Most of the growth can be attributed to the availability of energy – the Hydrocarbon Era. Read on and decide if you would have wanted our ancestors to have developed hydrocarbons any sooner.

the worth of the hydrocarbon was not as an energy source - as it is today - but for the purposes and reasons given above.

By the six or seventh century it had already found use as a weapon, being used as a fire ball to set fire to opponents' ships, buildings, etc. Launched as a fiery missile from catapults, it burned wherever it landed, even on water. Then, somewhere around the 15th century, there is evidence that people of the region were practising some form of refining, suggesting that they were beginning to understand the potential uses of this material. It was refined to produce oil for lamps.

At this time, all the hydrocarbon materials being traded, marketed, stolen - fought over - were taken from surface exposure - oil seeps, oil lakes, pits, etc., - or dug up from deposits such as tar sands. But Man's need for this product was growing by leaps and bounds. Empires were being made and destroyed over its possession; trade was flourishing from all corners of the known world. More of this stuff had to be found and it was the activities that followed that really mark the beginning of what is colloquially known as the Hydrocarbon Age. One event, which encouraged Man's entry into the Hydrocarbon Age but which, ostensibly, had no bearing on it, was the need to lift water for irrigation.

The name Huygens probably means little to anyone who doesn't wear spectacles, (in fact, it probably means very little to those that do!), but Dutchman Christiaan Huygens, apart from being a brilliant physicist who discovered the light wave effect and did a lot of work on lenses, in 1680 devised a means to mechanically lift water, by exploding small charges of gunpowder in a closed cylinder, so as to drive down a piston - the basis of today's internal combustion engine. Of course, it didn't work, but the principle was put in place. Part of the reason it did not work was the crudeness of the mechanical parts and the amount of energy sacrificed in trying to overcome the poor quality. Remember, energy cannot be created or destroyed.

Many people must have fiddled with the idea of using hydrocarbons as a means to drive an engine, but wasn't until almost two hundred years

after Huygen's experiments that a French engineer, Jean-Joseph Étienne Lenoir, in 1859 managed to convert a double acting steam engine into an internal combustion engine. By adding a spark ignition to the cylinders and, instead of steam, injecting a combustible mixture of coal gas and air, Lenoir created the first, continuous operation, internal combustion engine. Mind you, it was all of four percent efficient, most of the energy disappearing into the wide blue yonder as sound, heat and unburned fuel. But it set a precedent.

A company in North America, the Pennsylvania Rock Oil Company, that had made its money from rendering whale fat to make lamp oil, in the 1850s figured that digging this rock oil out was both time consuming and expensive¹ and developed a method, with the help of a certain gentleman, 'Colonel' Edwin L. Drake, of drilling a hole to extract the oil. The 'Colonel' was a title he gave himself, he being only a railroad conductor, as he felt it increases his stature with the media. The method he used was an adaptation of the salt mine drilling equipment which had already been in use for more than half a century.²

Using steel-faced chipping tools and heavier piping, the percussion drilling which became the modus operandi for oil well drilling for the next forty or fifty years, in 1859 brought about the first oil 'discovery' at Titusville in Pennsylvania, when Drake dug through into a cavern at 69 feet, got stuck, and oil floated to the surface of the water that filled the hole.

The Czar of Russia, hearing of this discovery and the potential it had to change the balance of power in the oil supply market, began the earnest development of the oil fields around Baku, on the coast of the Caspian Sea, resulting in the world's first blowout, when one of the wells struck high pressure oil.

Most notable amongst the investors that set up business in Baku were brothers Robert and Ludwig Nobel who, in 1873, set up the establishment of the Nobel Brothers Oil Extracting Partnership.

Then in 1901, in Spindletop, Texas, Anthony Lucas, using a rotary drilling rig, created not the first, but definitely the most famous American blowout, from a 300m deep hole, producing 80,000 barrels of oil per day, an unheard of amount from an oilwell, until that moment.

The world has never been the same since then.

Although the Egyptians are credited with using rotary drilling mechanisms to drill for water as much as 5000 years ago, it was not until much later, in 1500 that Leonardo DaVinci developed a design for a drilling rig that is similar to many of today's rigs. Today, most of the wells drilled use conventional rotary drilling rigs to dig their deep wells, although advanced technology is also changing that.

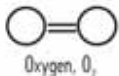
The more recent developments of the rotary drilling rig were without question the turning point in Man's utilisation of hydrocarbon as an energy source. Until then, oilwell drilling had been conducted by using a percussion type system, entailing dropping heavy, steel-faced tools into the hole, on the end of a cable or rope, so as to shatter the rock. The broken rock then had to be bailed out using a bucket.

This method was very limiting, both in time and in depth. One of the problems faced was the continuous incursion of water, from surface aquifers, into the well. Then someone came up with the idea of using this water as a means of removing the rock cuttings, as it already was doing, even in their bailing operations, by pumping a mud-like mixture down the pipe and up the outside, while rotating the pipe. This method extended well drilling capability from a few hundred metres to many thousands of metres. The oil industry as we know it today was borne.

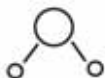
Before getting too deeply involved in the development of the hydrocarbon energy industry, it will help to get a better understanding of this product and its potential.

As mentioned before, hydrocarbons are produced by the decay and decomposition of once-living organisms that have been buried in anaerobic circumstances (i.e., an oxygen-free environment).


Hydrogen (atom)



Both are Molecules



Water H₂O

A Compound and a Molecule

The principle element in a hydrocarbon molecule is carbon, denoted by the letter 'C'. Another component is hydrogen, denoted by 'H', giving the name hydro-carbon. There are no other elements involved in pure hydrocarbons, but the abilities of these two elements to be attached to other elements make hydrocarbon molecules suitable for a vast array of compounds. (An element is composed of a single type of atom, a compound is composed of two or more elements – O₂, two oxygen atoms combined in one molecule, is an element, CH₄, methane, a molecule of one carbon and four hydrogen atoms, is a compound, as is H₂O, water).

Hydrogen is the simplest atom, with a single proton (positively charged elementary particle) surrounded by one electron (negatively charged elementary particle). The reason there is always two hydrogen atoms in naturally occurring hydrogen is that electrons are most stable when they inhabit what is known as a full shell or 'cloud' around the two hydrogen atoms. Single hydrogen atoms with one electron do not exist in nature for more than a brief moment in time, as they are highly reactive and will react with virtually anything. These 'clouds' surround all atoms and exist in various 'stable' states, or layers, according to the number of protons and the number of electrons, in a series that goes 2, 8, 18, 32, etc., one electron for each proton. (See Appendices IV, V)

Again, it is not the intention to teach basic chemistry, but what is presented here will help to understand the process of the utilisation of the energy inherent in hydrocarbons. Suffice to say that these 'islands' of stability have a lot to do with energy. Here, we are looking at the ionisation potential*

*The ability to change a stable atom into an ion, a charged particle, by the removal or addition of an electron to that atom.

of the individual electrons. Electrons in the outer stable shell are very hard to remove from the atom, i.e., the attraction of the positive proton to the negative electron is very high - it takes a lot of energy to separate them.

However, not all atoms can have stable outer shells. Let's see, two (2), would be helium. Helium is a very stable, single atom, unreactive gas. What has eight (8) electrons in the outer shell? It must have two plus eight protons - ten (10) - or neon, another stable, single atom, unreactive gas. And so it goes on. All the rest of the atoms are 'unstable' and usually are perfectly willing to 'share' electrons with another atom to reach a stable configuration. Those with a few electrons more than a complete shell will share one, or two electrons, while those with an almost full shell will willingly grab an electron offered for sharing. Such 'sharing' is referred to as a 'bond'. Some 'sharing' is very energetic, and is called an exothermic (giving off heat) reaction. Others, called endothermic reactions, may require energy (heat etc.,) to occur. Once created, these bonds are a store of energy.

Basic science tends to look at atomic structure as made of 'particles', discrete packages that can be identified as such. Basic science imaging shows a football-sized proton with a golf ball-sized electron whizzing around it at amazing speed. In actual fact, you can't see something like that, and it might benefit the reader more to think of electrons as 'clouds' of energy surrounding the proton, that have a very specific value, equal to, but opposite in charge to the proton. In this way, it is easier to understand how 'clouds' could merge and mix when atoms combine.*

*It might benefit the reader to get a hold of a book by Bill Bryson called 'A Short History of Nearly Everything' in which he gives very vivid descriptions of atoms, electrons, protons etc.



The classical concept of an atom was of a very dense core surrounded by electrons, not altogether incorrect, considering Ernest Rutherford's experiments that led him to his conclusions regarding the structure of the atom. "It was as if one had shot a large naval shell at a sheet of tissue paper and it had bounced back!"



The best way to imaging an atom is to think of it as a very dense core with a cloud of negative charge surrounding it. The higher the atomic number of an atom, the denser will be the electronic cloud. To all intents and purposes, atoms are about the same dimension irrespective of their atomic weight

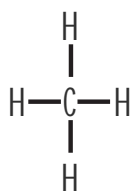


Atoms in a matrix look something similar to this, the atoms 'sharing' their negative energy clouds.

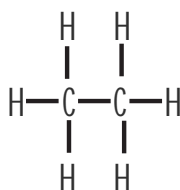
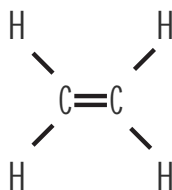
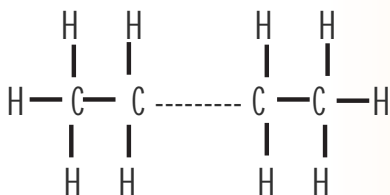
The simplest hydrocarbon is CH_4 - or methane. A single carbon atom has a valence of four (4), which means it has a strong desire to 'share' its four 'spare' spaces with other atoms to attain a stable eight (8) electrons in its outer shell. Knowing the above, a question arises. Carbon (six protons, six electrons) has an inner shell of two (2) electrons and an outer shell of four (4) electrons. Is it possible for carbon to reach a stable state (of 2) by 'lending' its four electrons? Not very likely. The energy required to separate electrons from its carbon proton nucleus would be impossible to achieve (see table in Appendix V). The carbon nucleus must 'attract' four more electrons. (One electron looks exactly the same as another electron to a nucleus – so it makes little difference where they come from!)

In chemistry, only the electrons of the outer shell participate in any reaction. And it is this desire to reach a stable shell of eight electrons that makes carbon so versatile, and such a good energy source. It will combine with oxygen, to produce CO_2 giving off energy in the process (a process we recognise as 'burning') or with another carbon atom, to produce a different compound, such as C_2H_6 , ethane. Carbon atoms can link together almost ad infinitum, in massively long chains, each with its complement of two hydrogen atoms, as in $\text{C}_{30}\text{H}_{62}$ a long chain hydrocarbon, which, at room temperature, is a solid. Hydrocarbons can range from gases, (methane, ethane, etc.,) to liquids, (petroleum, kerosene, etc.,) to solids such as bitumen.

Carbon atoms can combine with one, two or three carbon-carbon links, so that the three compounds, ethane, C_2H_6 , ethylene, C_2H_4 and acetylene, C_2H_2 are basically the same original molecule, C_2H_6 with one, two or three carbon bonds, minus of course the displaced hydrogen atoms. Each C-C bond makes the compound more reactive and, while ethane is flammable, acetylene is explosively so. The energy it takes to hold the atoms together, the bonds, is what is released when we 'burn' these hydrocarbons, turning the bond energy into heat energy (and light & sound). The explosive nature of acetylene is caused by the relatively unstable condition of its bonds – on Earth at least, it is a manmade product



Methane

 C_2H_6 or Ethane C_2H_4 or Ethylene C_2H_2 or Acetylene $\text{C}_n\text{H}_{2n+2}$

Carbon and Hydrogen atoms can combine in many different ways, making hydrocarbons one of the most versatile compounds available to Man yet all we can think of to do with it is burn it as fuel mostly.

and not found as a gas in nature although it does exist in interstellar space and on some of the gas planets' moons.*

Because of the decisions of chemists and scientists, in the 18th and 19th century, that all carbon compounds had to come from originally living organisms (by that time scientists had figured out that all living species contained carbon in their structure), the study of carbon and carbon compounds became known as organic chemistry. The fact that subsequent experiments produced very non-organic, non-living carbon compounds did not faze the scientists, even until today, so that the study of any carbon compound is referred to as organic chemistry. This, however, included almost 95% of all known compounds, making carbon unquestionably the most versatile element in the Periodic Table, the list of all known elements[†].

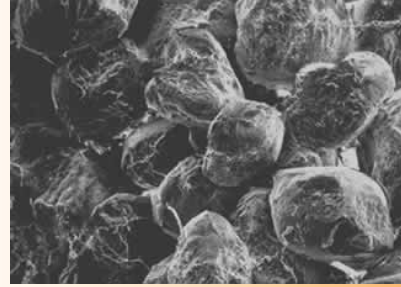
The Earth is composed of various rock types, all of which, at least the ones of any interest to us in this discussion, occupy the first few kilometres of the planet's skin. These are sedimentary, metamorphic and igneous rocks. Sedimentary rocks are formed by the decomposition of existing rock by weather action and water (sandstones), or by the death of marine creatures (limestones), the product of which is washed down into sedimentary basins or shallow sea beds. As they accumulate, the overburden, or accumulated weight, drive the sedimented rock deeper and deeper into the Earth's crust, compacting the particles which, over time, become cemented together by chemical deposit from interstitial water.

If driven deep enough, the rocks undergo a conversion known as metamorphosis, brought about by the heat rising from the Earth's Mantle,

* However, as a child, I still remember using calcium carbide in a makeshift lamp, similar to that used in miners' lamps many years ago, adding water to it to produce acetylene. (I also remember the row I used to get because of the soot it created...)

[†] It might be an interesting point to note at this juncture, for those of you who appreciate such facts that, despite the importance of carbon to our survival, it constitutes only 0.008% of the total composition of the Universe. Hydrogen accounts for 92.7%.

turning them into metamorphic* rock. Sometimes rocks are metamorphosed by coming into close proximity to igneous rocks, molten intrusions from the waxy-like substance that lies beneath the Mantle, which, by the way, also drives plate tectonics, another facet of the Earth's geology which has a major bearing on the availability of oil and gas.

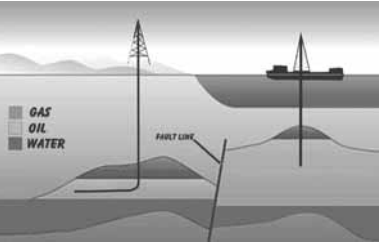


By a process of elimination, we can see that the only rock in which oil or gas can be formed, must be sedimentary. Igneous rocks are out of the question, as they are molten at the time of deposition and, as in the case of basalt or granite, crystalline in nature. Metamorphic rocks may have at one time been the 'kitchen' of hydrocarbons, before they became metamorphosed, but anything included in the rock structure would have been vaporised and destroyed before the rocks reached their final condition.

Note that I said 'formed in'. Oil and gas can be found in all three rock types, depending on the situation. Here, we digress for a moment and go back to the waxy-like substance beneath the Mantle. Much like the boiling water in a kettle, this molten rock is writhing and rolling, driven by the nuclear furnace that makes up the largest part of the Earth's volume. The movement of this 'plastic' rock is unbelievably slow, but move it does. Piggybacking on it is the Mantle, carrying the continental plates that make up the skin of the Earth and the land on which we walk. The upheaval caused by this movement results in the fracturing and movement of the surface rocks, creating large fissures, uplifting whole sections, dragging others down (earthquakes).

This micrograph shows what sandstone in a reservoir might look like. Note the void spaces. There is adequate room to hold oil and/or gas. The question is, do these spaces (porosity) connect adequately (permeability) to allow the oil to flow towards the well? One of the inhibitors is what is known as 'wet-ability', whether the individual particles are oil wet, or water wet. If the particles are water wet, the oil will be repelled and will flow more easily out of the reservoir. If the rock faces are oil wet, it will cling onto the oil, making it much more difficult to produce.

*Metamorphosis is the conversion, through heat, of the chemicals that make up the sedimentary rock. There is sufficient heat to alter the chemistry of the rock, but insufficient to melt the rock completely, resulting in a different kind of rock, e.g., crystalline as opposed to particulate.



Rock layers are twisted and bent, frequently sheared by tectonic forces, to form traps into which gas, oil and water may accumulate. By knowing where these traps are, mankind was able to drill into them and recover the oil and gas. Pressure, from inflowing water drives the oil or gas towards the upper regions of the reservoir. Gas can be re-injected into the 'gas cap' to drive more oil out. Water may also be injected into the water zone for the same purpose.>>



This picture, of an outcrop in Borneo, vividly shows the power of tectonic forces in being able to literally move mountains. The striated layers are sequential depositions in a water environment, either lake, or sea, of sand and silt, or the skeletal remains of marine creatures which have been compressed, solidified and then upthrust by enormous forces. The rocks shown here are being thrust upwards, they are not slipping downwards into the surrounding rock. The White Cliffs of Dover are an example of upthrust sedimentary rock.>>

Any rock that has open pores, fractures or spaces in it, can become a repository for oil and gas. All that is needed is a seal. That can be another rock, such as shale, which is made of so small particles to be completely water- and gas-proof, a salt plug, which is crystalline and therefore impervious, or another rock which has weathered the upheaval better than the rock below and is not fractured.

The oil and gas seeps mentioned before come from fractures in the rocks overlying the reservoir rock in which the oil and gas has accumulated. Oil and gas seeps still occur today and are used as a means of determining the location of potential hydrocarbon traps.

Hydrocarbons do not exist in pools or caverns as might be thought but between the rock particles of sandstones or in the minute fractures that exist in the likes of limestones. What is required of all rock types that hydrocarbons are found in, if they are to be produced, is interconnectivity, or permeability. The porosity of a rock is its inherent space available to a liquid or gas, while its permeability is the amount of interconnectivity that will allow the gas or oil to flow from one part of the rock to another.

When explorers first started drilling for hydrocarbons, the wells they drilled were very shallow, in the order of a few hundred metres. Today, wells are drilled thousands of metres into the Earth, both on land and on sea.

The technology today has been developed to such an art that wells can be drilled many kilometres horizontally away from the drilling rig, increasing the scope and ability of the wells to produce from even remote locations. The driving force behind this development, of course, is cost. Hydrocarbons

are still the cheapest form of energy available to Man, even though we know that we are using a finite resource.

As mentioned before, Man's involvement with hydrocarbons stems from millennia before, where their applications ranged from waterproofing of reed baskets, through jewellery making to medication. It was this last use that blossomed in the 17th and 18th centuries. Of course, oils were used for lighting as well, but few attempts were made to refine any of the hydrocarbons dug up.

The Industrial Revolution in Britain and Europe was built on coal as a means of supplying power. Great furnaces belched thick, black, sooty smoke into the atmosphere for centuries, creating the steam that drove the machinery of the revolution. Even today, huge smoke stacks throughout Europe and the rest of the world, can still be seen pouring their noxious fumes into the atmosphere, even though technologies have mitigated much of the more deadly contents of the exhaust streams.

The problem arises from the cheapness of coal, relative to the cost of oil and gas extraction. Most of the extracted oil goes to transportation, not for power. Natural gas availability is still insufficient to replace completely the use of coal as a power source, although slowly, things will change.

As the Industrial Revolution evolved, machines were designed to make other machines. Products, manufactured in mass, had to be moved. Shipping, driven by coal-burning steam engines, began to be developed, but land transport was still highly dependent on the horse drawn wagon.

Going back to the internal combustion engine, a few years after Lenoir's heroic attempts, (I say heroic, because what he did was heroic. If he only knew the risks he took - poor quality steel, questionable finishing, highly explosive mixture - he's lucky he didn't get killed), another Frenchman in 1862, Alphonse Beau de Rochas, a scientist, patented what he called a four stroke engine. Although he never built one, several people after him did, notably Nikolaus August Otto, who built what was to be known as the 'Otto cycle', four stroke engine. This was followed later by the

invention by Gottlieb Daimler in 1889, of what became the forerunner of all of today's internal combustion engines.

Another noteworthy was Rudolf Christian Karl Diesel, a German, born in France, who devised the engine that would be named after him, the diesel engine. Basically the same as the Daimler engine, this one used compression to combust the oil used as fuel, instead of the spark plug to ignite the gasoline, as used in the Daimler engine.

So, in a very short period, a matter of 30 years, from Lenoir's engine in 1859, to Daimler's engine in 1889, Man had developed a means of usefully converting hydrocarbons into work. The days of the horse-drawn draught wagon were numbered! Even so, it took a man by the name of Henry Ford and the use of machines and mass production, to get the world off of four legs and onto four wheels. These early vehicles were not particularly efficient, but neither were the steam engines used on the rail system. Although the internal combustion engine was invented and first built in Europe, its use was restricted to gentlemanly races in such gloriously named vehicles as the Peugeot Vis-à-Vis, (four people sat facing each other in a two by two arrangement, similar to the old stagecoaches. Don't ask who drove), Panhard & Levassor, de Dion, at mind-shattering speeds of 12 to 15 miles per hour. Within ten years, as Henry Ford was just beginning to build his Model T, these European engine and car manufacturers were hitting 100 mph, in huge, 14 and 15 litre engines (by comparison, your Nissan or Honda or Ford today probably has a 1.6 to 2.0 litre engine.)

But Henry Ford was more pragmatic. He knew that to succeed in business, he had to mass-produce, at an affordable price. He could hand-build a very expensive car, like Daimler, for the few rich and famous, or he could mass-produce a simple, cheap automobile that even Joe Average on the streets of America could afford. One of his more admirable comments went something like "You can have it in any color you want, so long as it's black". That was Henry Ford.

You could carry coal, like the steam driven locomotives, which cost almost as much to transport as it provided in useable fuel - its power to weight ratio was very low. The internal combustion engine provided a much higher power to weight ratio, i.e., the amount of useful energy derived from a fuel as a function of the amount of fuel that needed to be carried or, in other words, the efficiency of the engine. A steam engine might have an efficiency of 8 to 10%, an internal combustion engine's efficiency was in the twenties.

It is fairly safe to say that Henry Ford played a major part in the development of America as we know it today. Once upon a time, a car was a luxury. It soon became a necessity as the population spread out over the country, opening up the land and allowing the nation to develop into what it is today. That development brought with it an increased demand for energy sources - hydrocarbons especially - as a compact, transportable fuel. You could carry coal, like the steam driven locomotives, which cost almost as much to transport as it provided in useable fuel - its power to weight ratio was very low. The internal combustion engine provided a much higher power to weight ratio, i.e., the amount of useful energy derived from a fuel as a function of the amount of fuel that needed to be carried or, in other words, the efficiency of the engine. A steam engine might have an efficiency of 8 to 10%, an internal combustion engine's efficiency was in the twenties.

Because of this changing form of transport, the demand for hydrocarbons increased tremendously, bringing about a revolution in the oil exploration industry. Already, by 1872 a small strip of land in an otherwise uninhabitable part of Northwestern Pennsylvania, close to where Drake first discovered oil in America, had become the busiest piece of real estate in the US⁵. Townships sprung up everywhere, as companies were set up to exploit this new product, called petroleum, which was bringing millions of dollars into people's pockets. There were no less than three railroads running through the region, railroads that were to become the centre of one of the greatest battles of the 20th century.

Up until the 1850s, the oil being extracted was more of a nuisance than a saleable product. It was being sold quite extensively, but as a medicine or embrocation. Samuel M. Kier, a salt prospector, had already found a use for the oil, '...which came up with the saltwater, was of sufficient quantity to be a nuisance and Kier sought a way to use it. Believing it had curative qualities he began to bottle it. By 1850 he had worked up



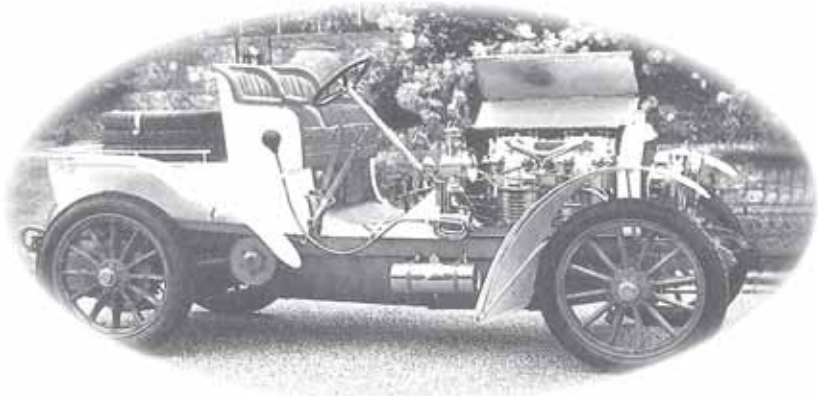
A Stanley Steamer - it took half an hour or more to warm up before it would move. Not exactly the car to nip down to the Mall for groceries when you're in a hurry.



Henry Ford with his Model T



The Peugeot Vis-à-Vis



A Classic 'Gentleman's car' of the early 20th century



A beautifully maintained 1910 Touring Model T owned by Jacquie & Roland Palmatier, Durham, NH, courtesy of the Model T Collectors' Club

this business until 'Kier's Petroleum', or 'Rock-Oil' was sold all over the United States⁵.*

Then, in 1854, arrived a man who took rock-oil more seriously. His name was George H. Bissell, a one-time graduate of Dartmouth College. On a visit to his old college, he was shown the bottle of rock-oil. His old professor contended that it was as good, if not better, than coal for making illuminating oil.

The oil came from oil springs located in Northwestern Pennsylvania on land belonging to a lumber firm, Brewer, Watson and Company. These springs had long yielded a supply of oil which was regularly collected and sold for medicine, and was used locally by mill-owners for lighting and lubricating purposes.

Bissell, impressed with the commercial possibilities of the oil, at once organised a company, the Pennsylvania Rock-Oil Company, the first in the United States, and immediately leased the lands on which these oil springs were located.

'He then sent a quantity of the oil to Professor Silliman of Yale College, and paid him for analysing it. The professor's report was published and received general attention. From the rock-oil might be made as good an illuminant as any the world knew. It also yielded gas, paraffine, lubricating oil. "In short," declared Professor Silliman, "your company have in their possession a raw material from which, by simple and not expensive process, they may manufacture very valuable products. It is worthy of note that my experiments prove that nearly the whole of the raw product may be manufactured without waste, and this solely by a well directed process which is in practice in one of the most simple of all chemical processes."⁵

* Compare this to the unending legislation still being put in place today, to try and protect people, especially young children, from ingesting hydrocarbon products, as they are considered dangerous and potentially carcinogenic.

Possibly the most prophetic words ever uttered by one person to another. By February 1, 1860, oil was selling at eighteen dollars a barrel! Conversely, by the end of 1861, so many people had rushed to participate in this 'Black Gold' Rush and so much oil was being produced, the price collapsed to ten cents a barrel. So what's new in the world?

A major problem faced by those who were producing the oil was how to get it out of one of the most inhospitable places in the Americas. The obvious answer was to put it into barrels* (hence the term 'a barrel of oil') and take it out by horse and wagon. This turned out to be a very lucrative venture for the farms in the area, as the farm boys hitched up their teams and offered their services. Sometimes, as many as a hundred wagons could be seen on the road at a time, all hauling barrels of oil. These teamsters were not averse to a little brawling once in a while to get what they wanted, and were notorious for their 'black snake' or long, leather horse whip, which could soon change a person's mind.

But events were to catch up on the transportation of this new product. The first pipeline to be built and operated infuriated the teamsters who immediately tore it apart. The next pipeline built, they actually set on fire, along with the tank farm, which was used for holding the oil prior to it entering the pipeline. Eventually though, the pipelines won out and the teamsters had to give up, ungraciously in the most part. They were losing out to a much greater force, the railroads.

Although oil was first discovered in Pennsylvania and the first blossoming of the industry began there, because of the better connections and transportation systems from another state to points beyond, it was not long until a large refining industry evolved in Cleveland, Ohio. Its thirty something refineries were selling products all across the western seaboard while Pennsylvania was still struggling with moving its oil from wellhead to market.

*A barrel of oil is, by definition, 42 US gallons. There are 1.200952381 US gallons in an Imperial gallon.

One young Cleveland man who had an eye on the oil-refining business, had remarkable commercial vision - a genius for seeing the possibilities in material things. This man's name was John D. Rockefeller. Although he was only twenty-three years old when he first went into the oil business, he had already got his feet firmly on the business ladder, by his own efforts.

Early on, he learned the value of investing money: "Among the early experiences that were helpful to me that I recollect with pleasure was one in working a few days for a neighbour in digging potatoes - a very enterprising, thrifty farmer, who could dig a great many potatoes. I was a boy of perhaps thirteen or fourteen years of age and it kept me very busy from morning until night. It was a ten-hour day. And as I was saving these little sums I soon learned that I could get as much interest for fifty dollars loaned at seven per cent. - the legal rate in the state of New York at that time for a year - as I could earn by digging potatoes for 100 days. The impression was gaining ground with me that it was a good thing to let the money be my slave and not make myself a slave to money."⁵

By 1870, through astute business sense and not a little brass neck, John D. Rockefeller combined the two oil refining companies and one marketing company in which he had either a controlling interest or he owned, into one - The Standard Oil Company.

“This is a story of a human enterprise that has shaped and will continue to shape civilisation... Those who got rich became filthy rich...”

Michael Economides & Ronald Oligney in 'The Color of Oil'⁶.