Conservation and Civilization.

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Not until recently has man begun to think of nature's resources in the light of the old saying that "one can not eat his cake and have it." Today the subject of the conservation of these resources is being discussed by men of science in every civilized country on the globe. Nevertheless it must be admitted that the full import of the question is not yet appreciated by many science men, while the public generally scarcely knows what the discussion is about. A few years ago the writer heard an address in which the speaker pointed out the importance of conserving the soil. A fellow citizen in speaking of the address said he did not understand what the speaker meant, that the earth is made of mud and that no one need be fearful of a shortage. The observation led to the reflection that people too are made of mud, some of it not very fertile. Perhaps our citizen did not know that the average productivity of the unfertilized soil of Indiana is but half of what it was when he was a boy. Perhaps he does not know that all animal life is dependent on plant life, and that plant life is dependent on a few soluble constituents of the soil which form but a small and diminishing per cent. of what he calls mud. Perhaps he does not know that the removal of timber and the cultivation of hillsides permit the rains to dissolve and carry away the soluble constituents and so impoverish the soil, and that every year thousands of acres of land, here in his own State, Indiana, are ruined in this manner. He does not know that every year the Mississippi River robs the Mississippi Valley of hundreds of millions of tons of that upon which its fertility depends, and that all other streams are doing relatively the same thing.

But I am not to discuss the conservation of our soil, nor the conservation of our timber or our food supply. I shall not discuss the conservation of air or water, although the time has passed when we can say "as free as the air we breathe or the water we drink." Good pure air is not free to everybody, by any means. If it were there would be no

"white plague." Nor is good pure water free. Sometimes it can not be obtained at a price, as some of us well know. New York City is just now completing an additional water system, this last system alone costing one hundred and eighty millions of dollars.

I wish to direct your attention to a phase of conservation that receives less consideration than is generally accorded the conservation of timber, food, and soil. I wish to consider our fuel supply, and its relation to civilization.

I shall begin by defining the word energy as the capacity for doing work; that is, the capacity for exerting force through space. Anything that can do work has energy stored in it, the quantity of energy being measured by the amount of work the thing can do. For instance, a clock spring or a clock weight has energy which it expends as it runs the clock; a battery has chemical energy which it expends when it rings a bell or drives a motor; a head of water has energy which it expends when it drives a turbine; gasoline has energy which it gives out as it heats a kettle or drives a motor car; a chunk of coal has energy which it expends when it heats our home or produces the pressure to drive a steam engine.

If we represent all the heat energy in the universe by the letter "h", all the chemical energy by "c", all the electrical energy by "e", and so on, using a different symbol for each and every one of the many forms of energy, then we may express the law of the conservation of energy in the form of an equation—h+c+e+ all other kinds of energy=a constant.

This law expresses the fact that energy is indestructible. We can neither create it nor destroy it. What then do we mean when we say that we should conserve and save our energy? To answer the question we shall need to consider two other laws or principles of energy, known as the Principle of Transformation of energy, and the Principle of Dissipation or Degradation of energy.

By transformation of energy we mean the conversion of energy of one form into energy of some other form. For instance, the energy of the coal is transformed in the boiler into the heat and pressure energy of steam, the engine converts this into a mechanical energy of motion; this may be used to drive a dynamo which converts it into electric energy, this may be passed through a lamp and be converted into light energy or it may be used to drive a motor which converts it again into mechanical energy, and so on. There is known no kind of energy that man can not

transform into any other form of energy. He may change almost at will the relative value of the energy terms on the left side of his energy equation, but he can not change their sum. No energy is lost in any transformation. The total remains constant.

In actual practice, however, when we attempt to transform or use energy, we find that more or less heat energy is generated in the process, and that this heat energy is dissipated through space. No machine is frictionless, no wire is without its electrical resistance. There is no motion of matter or electricity that does not result in the generation of heat which can not be utilized, heat which soon disappears forever in space. This energy is not destroyed, it is lost. It is easy to transform energy of any kind into heat energy, but it is impossible to transform all of any quantity of heat energy into energy of other kinds. Our best steam engines have an efficiency of some twenty per cent., the efficiency of the usual engine is not over ten per cent. This means that w waste from 80 to 90 per cent. of the coal and utilize from 10 to 20 per cent. Our best tungsten lamps give us only about 10 per cent. of the energy of the electric current required to operate them, and since the engine that drives the dynamo has an efficiency of, say 10 per cent., the tungsten lamp gives us as light only 1 per cent. of the energy of the coal, 99 per cent. being wasted in the form of dissipated heat. So we have the principle of the dissipation of energy; however we transform energy, a fraction of it—usually a large fraction of it—is always dissipated as heat and is forever lost. Thus while the total quantity of energy in the universe remains constant, the useful or available energy is rapidly diminisning. All forms of energy are tending to go into the form of heat, to run down hill as it were, as heat is regarded as the lowest form of energy. Consequently this Principle of the Dissipation is sometimes called the Principle of the Degradation of energy. It makes no difference what the final temperature of the universe may be; when all other forms of energy have been transformed into heat the heat energy will be useless. We can not use heat energy except as it runs down hill, from points of high temperature to points of low temperature. It is doing this all the time. Diffusion is a property of heat, and must result sooner or later in a state of uniform temperature and consequently in the disappearance of all available energy.

Perhaps you ask why we should worry about the condition of things a million years hence? The reply is that we need not do so, but that we may well take thought of what the condition may be before the twentieth

century shall have ended. No doubt the disappearance of all available energy is a matter of millions of years, perhaps of billions of years. But the disappearance of so much of our available energy that what remains may be entirely inadequate to supply the demands of a civilization such as we now have, is not a matter of millions of years, not even of thousands of years.

The progress of man has been proportional to his mastery of, and use of, Nature's resources. Thus we have the Stone Age, the Bronze Age, the Iron Age, and the Steel Age—the age of today. A 1914 model automobile, if made of bronze or iron, would not run a mile. The invention of the automobile could not have preceded the invention of steel. Steel made possible the light weight engine of high power, without which flying machines would be impossible. Without steel most of the weapons, and instruments, and machines of today would be impossible. Without power they would be useless. So this has been called the Age of Power or the Age of Energy, or better still, the Age of Coal Energy, for coal supplies almost all the energies required to do the work of the world. King Coal reigns with a lavish hand. We feast at the table, apparently unmindful of the fact that we are nearing the dessert course of his final banquet.

Our boasted triumphs over past generations are due to the fact that we have learned to use energy freely. We are not superior to those of earlier ages, in art, in architecture, in music, in intellect. We are vastly superior to them in our ability to make use of Nature's mineral resources. I might even say in our ability to use coal, for without coal the production of iron and steel would be practically impossible and the mineral resources of the world would remain undeveloped.

It is high time that we were awaking to the fact that civilization as we know it must disappear from the earth when the available energy has been exhausted. Concern over the social, intellectual, religious, and political state of future generations is of secondary moment compared with the question of the existence of civilization itself.

Each individual knows that he must die. But if he thinks the event somewhat remote he scarcely gives the matter a thought. He may even indulge in things that he knows will surely hasten the event. So with a race. We give no thought for the morrow, but continue to use and to waste Nature's resources, knowing full well that the death of the race is the inevitable result, and that our prodigality is speeding the day. We make the mistake of supposing that the day is indefinitely removed. We

calm ourselves with the thought that the human race has inhabited the world for thousands, perhaps millions of years, and still Nature is bountiful. But we should remember that not until this century has there been any considerable draft upon Nature's store of energy in the form of coal.

Coal was not discovered in the United States until some two hundred years after the discovery of America. It was seventy years after its discovery before it was commercially mined. For many years the output of the mines was very small. Lately, the disappearance of our forests and the astonishing increase in the use of machinery have combined to make enormous demands on our mines. The coal used in the United States during the past nine years is in amount equal to the total consumption up to the year 1895. The output of the mines for the year 1912 was 535 million tons—about five tons for each man, woman, and child in the United States. The figures relating to petroleum are just as significant. The industry began in 1859, and it was twenty-four years before the entire output was equal to that of one year now. The output of the last eight years equals all that produced before.

Natural gas is all but a thing of the past. When scientists foretold the speedy exhaustion of the supply and cried out against its criminal waste, their cry was unheeded and the waste went on. If all the gas wells had been properly cared for, and if all gas had been sold through meters, we should have had the blessings of natural gas for a century to come. People scoffed at the idea of natural gas failing. So did the newspapers throughout the entire gas belt. The introduction of meters was fought by papers and patrons, until the finish of natural gas was in sight. Instead of educating the people to economy and care, the papers incited them to extravagance and indifference.

We are now passing through a somewhat similar experience with petroleum and coal. Many of our oil fields have been exhausted and abandoned. No wonder, when we note that the production of petroleum of a single year is a quarter of a billion barrels. This enormous production has been made possible only because of the discovery of new fields to replace the exhausted fields. The discovery of new fields can not continue indefinitely. Most of our territory has been explored. It is only a question of time, and not a very long time, when oil too will have become a thing of the past. There will remain but one natural fuel, coal, to stand between us and a return to a primitive type of civilization.

The life of the coal beds has been variously estimated at from one hundred to five hundred years. The time will be longer or shorter, depending on our frugality or our prodigality. Yet our newspapers, among them the same ones that fought the use of meters for natural gas, fight the utilization of the power of Niagara Falls, calling upon state and national governments to preserve this wonder of Nature, the inference being that the use of the power of the Falls would mean the destruction of the Falls. Of course Niagara should not be exploited for the profit of individuals or corporations, nor should the Falls be destroyed. It might be arranged to permit, at certain times, all the water to go over the Falls for the delight of man. But in the opinion of the writer it is short-sighted, it is almost criminal, to permit millions of horse power of energy to go to waste, continually and continuously, merely for our enjoyment. Does the reader think it right to burn millions of tons of coal each year that might be saved for future generations, all in order that we—some of us—may see the glory of Niagara? Who is sordid? The man who is willing to forego a magnificent spectacle for the good of future generations, or the man who would feast his eyes and let future generations freeze? How does the Niagara waste differ in principle from the uncapping and lighting of a natural gas well with the gas under a pressure of hundreds of pounds per square inch, in order that people might hear the roar of escaping gas and see the heavens illuminated by a giant flame?

I remember that when the American Association for the Advancement of Science met in Indianapolis in 1890, the committee on entertainment arranged for an excursion through the Indiana gas belt and a natural gas display. At one city pipes were laid in the river and the gas liberated under the water. We saw the river, in appearance, converted into a seething cauldron. The sight was grand, but not pleasing. A man of science could not avoid the thought that we were being entertained at a fearful cost to future generations. Recently the writer's attention was called to the possibility of that display in the end conserving the gas supply instead of hastening its exhaustion. The display may have served to arouse sentiment against such wanton waste and consequently to hasten legislation prohibiting it. This may have been true in this particular instance, for those who saw the waste were those to whom such a thing would make a strong appeal. But people generally saw reckless extravagance on every hand and were a party to it. The writer recalls

a gas well within six miles of his father's home that was permitted to burn almost a year before the flow was stopped. The gas wasted from that well alone would be sufficient to supply a city of moderate size for a hundred years. Truly we are reaping where we have not sown, and are leaving but little of the harvest for future generations. To realize the truth of this statement you have but to consider the enormous development in the use of mechanical energy during this generation, and the necessarily enormous consumption of oil and coal required to supply that energy.

The one-horse buggy has been superseded by the thirty horsepower runabout, the two-horse carriage by the forty-horse touring car, the two-horse wagon by the sixty-horse auto truck, the two-horse stage coach by the five-hundred horsepower locomotive. The horse car has given place to the electric car, the sail ship to the steamship or dreadnought, the canoe to the motor boat, the bicycle to the motorcycle, the foot or hand press to the power press, the typesetter to the linotype, the tallow candle to the electric lamp.

Once man ate what his own fields produced; now much of his food comes to him from the ends of the earth. Once man was content to worship in the little church at the cross-roads; now he must attend conventions in Boston or Los Angeles. Once he thought twenty miles a journey; now he travels a thousand miles to see a ball game.

Now the house wife must have her electric irons and cookers, power washing machines, and vacuum cleaners. The farmer must have his feed choppers, shredders, threshers, and pumps, all operated by power, lately by gas engine power. The thousands of windmills that dotted the country twenty years ago have disappeared—replaced by gas motors. The grocer grinds the coffee by electricity and delivers it with an automobile. The absurd extremity to which we have gone in the application of power is illustrated when an auto delivery wagon calls for and delivers a ten cent package of laundry. These things are little things, but they illustrate the spirit of the age. We do nothing ourselves that we can get Nature to do for us. We give no consideration to the fact that we are burning the condensed sunshine of bygone ages. Our only question is, "What does it cost?" What does it cost *us*? Not what it has cost Nature, or what it will cost future generations.

The value of coal is fallaciously reckoned on what it costs to mine and transport it. The fact that coal represents energy stored by Nature

through countless ages of time is not given a moment's thought. Figuring this way, if we can manufacture ice a penny a ton cheaper than we can harvest the natural ice, we proceed to burn coal to make it. Think of the waste. Burning coal to make ice, when all the ice we need could be had for the harvesting. You say that natural ice is not produced in the tropics. Neither is artificial ice, in any quantities.

We flood our streets with oil, because we think it a cheap way of keeping down the dust; cheap only because we fail to consider the energy content of the oil and what it has cost Nature to produce it. The time will come when such extravagance will be prohibited by statute.

The fact is that we fail to realize that oil and coal are a legacy that has come to us from bygone ages, deposited in Nature's bank. We are spending our substance in riotous living, but unlike the prodigal have no place to go when it is all spent. Doubtless something will fall on our neck, but there will be no fatted calf.

The writer has painted a gloomy picture, such a picture as would have been painted twenty years ago, with dark clouds hanging everywhere about the horizon. However, the picture needs but one change to represent the conditions today. There is a rift, a small rift, in the clouds; a rift that may close and leave us again with leaden and ever darkening skies: a rift that may open wider and wider and leave us finally with the glorious sunshine of a cloudless sky. Whence the rift?

The energy content of matter depends on position and motion, not only on the position and motion of the mass as a whole, but upon the position and motion of the constituent parts. Experience tells us that the energy liberated during any change is relatively greater the smaller the parts taking part in the change. For instance: the energy required to change a gram of water into steam, a change of position of the molecules, is twenty times as great as the energy of a speeding rifle bullet of the same mass. To effect an atomic change, that is, to separate the hydrogen and oxygen atoms which form the water molecules, requires five times the energy involved in the molecular change. When the atom itself breaks up, disintegrates, relatively enormous quantities of energy are liberated.

Radium is a substance in which this electronic or sub-atomic change is going on continuously and spontaneously. It is continually throwing off or radiating minute particles, and so we say that radium is radioactive. A mass of radium gives off enough energy every hour to melt more than

its own weight of ice; and it does this day after day, year after year, and it will continue to liberate energy until the last trace of the radium has disappeared, a process that we have every reason to believe will require ages of time.

Many other substances beside radium are known to be radioactive. All substances may be more or less radioactive, the difference being one of degree rather than of kind. However this may be, we now know that there is stored within the atoms of matter quantities of energy, intra-atomic energy, beyond the powers of man to estimate. This is the rift in the clouds. It was produced by the discoveries of Becquerel and the Curies.

The rift in the clouds is not quite as wide as it was a few years ago, for so far man has failed absolutely to influence these radioactive processes in the slightest degree. Whether at the temperature of liquid air or the electric furnace, in boiling acids or alkalies, whether in a vacuum or at a pressure of a thousand atmospheres, whether inside or outside the strongest electric and magnetic fields man can produce, the rate of disintegration and consequently the rate of liberation of energy appears to be absolutely constant. Perhaps we may not hope to be able to control a change in the atoms themselves, for have not the atoms existed through countless ages and successfully withstood pressures and temperatures in Nature's laboratory exceeding any that man can bring to his service in the chemistry or physics laboratory?

That this intra-atomic energy exists is not theory. It is a fact that is as well established as any fact in science. Man hopes some day, somehow, somewhere, to unlock this infinite storehouse of energy. Today Nature stubbornly holds the key. The probability of man being able to wrest it from her is anything but bright. But we should not be, we must not be, discouraged, for it is our only hope. If the secret is ever discovered and we succeed in tapping this supply of energy no mind can imagine the hights to which civilization will mount by leaps and bounds. If the secret eludes us civilization is doomed to return to a primitive state from which it can never emerge.

Perhaps you urge that our estimate of the life of the coal beds is too short. If it were in error by one hundred per cent., and no authority claims as much, the depletion of our coal supply is simply moved forward a few generations. The ultimate outcome is unchanged.

Perhaps you say that the writer has failed to consider the possibility

of using the energy of the sun's rays. You should remember that sometimes we do not have enough sunshine in Indiana in a week to supply heat for a cup of coffee. It is a fact that where heat is most needed, and when it is most needed, to heat our homes and run our factories, there and then is the least sunshine. Imagine London depending on sunshine for heat and power. In winter when we need the most heat the sun shines the fewest hours per day, the fewest days per week, and the sun's rays are most oblique. Taking into consideration the necessarily low efficiency of any engine working between the temperature limits of an engine for using the sun's radiation, and the very large surface from which the energy would have to be gathered, men of science are agreed that the prospect of a practical sunshine engine are exceedingly remote.

Finally it may be argued that the writer has failed to see a rift in the clouds arising from the possibilities of water power. The answer is, there is no rift there. No doubt the use of water power will postpone the gathering of the clouds, but it will not disperse them. Leaving out of consideration the fact that water power is usually most abundant where least needed, that the available power varies greatly with the seasons, that the available water power is diminishing from year to year with the removal of forests and the draining of swamp lands, let us remember the fact that the total water power of the world is almost nothing compared with man's demands.

A single ocean liner burns fifty car loads of coal per day. To supply the power for such a liner would require ten such water power plants as the one on White River at Williams, near Bedford, which cost several hundred thousand dollars. Then, too, it would require all the ten plants to operate at full capacity, which the Williams plant can not do a considerable portion of the year, the supply of water being insufficient. The writer is informed that it is not using water power at all as this is being written.

Every fifteen days the new automobiles marketed by a single manufacturer of cars of low horsepower equals the entire water power development of the Mississippi River, at Keokuk. Every thirty days the new engines turned out by this one firm equal in power the total water power developed at Niagara. The total horsepower of the automobiles now registered in the United States is greater than the estimated total available water power of the country.

It would appear that one need not go further to show the utter

inadequacy of water power as a substitute for oil and coal. Those who think otherwise usually consider the question from the standpoint of factory power only, leaving out of consideration the enormous quantities of energy required to heat our homes, and to supply heat for such processes as ore smelting, cement manufacture, brick, tile and glass making, and thousands of others. To equal one ton of coal per month for heating purposes one would require the entire output of a fourteen horse-power plant, running twenty-four hours per day thirty days per month. If there are five hundred thousand families in Indiana and if each family consumes an average of two tons of coal per month during the winter season, the consumption is the heat equivalent of fourteen million horsepower. Remember, too, that Indiana is not a very populous State and that its climate is not severe.

Professor Soddy states the facts in his little volume on "Matter and Energy" when he says that "the age in which we live, the age of coal, draws its vivifying stream from a dwindling puddle left between the comings and goings of the cosmical tide."

We are to "witness a race, a race between science on the one hand and the depletion of our natural resources on the other hand." This race will be run chiefly by pure science, not by applied science. Engineers and inventors make their reputations and their fortunes by devising new and improved methods of using our natural resources; they are not concerned with the atom, the latest and the greatest energy reservoir discovered by man. We must look to such scientists as Becquerel, Curie, Rutherford, Ramsay. We must look to the humble, overworked, underpaid scholar toiling away in his laboratory. If he fails us, darkness comes.