Powering the Future

How We Will (Eventually) Solve the Energy Crisis and Fuel the Civilization of Tomorrow
by Robert B. Laughlin - 2011
Synopsis by Craig Weightman

Ch 1 - Armchair Journey

This book takes effort to read, but the author rewards the reader with an objective perspective about the different options our future is likely to take and why. Robert B. Laughlin is a Nobel Prize winner in Physics and fully knowledgeable regarding the scientific probabilities of future energy research.

The author attempts to look at the world's use of energy in 200 years. The reason for this is to bypass all the arguments of how we will get to that point and look at a world where coal, oil, and natural gas are things of the past. In this manner we are able to separate the technical matters from the political concerns - political concerns being primarily how we will make this transition. The issues of energy turn out to be especially easy to think through in hindsight - we will probably have cars, may have airplanes, and most likely will have electricity.

We can predict the energy situation so far in the future reasonably reliably because it's circumscribed by elementary things - the laws of economics will still hold, people will be similarly motivated as they are today due to genetics, and energy is ruled by a powerful physical law - energy will still be conserved and will have to come from somewhere.

Since climate and energy are two different things and since humans will always opt for the cheapest solution when pushed, we need to closely examine the ability of man to impact the climate before we discuss probable energy solutions.

Ch 2 - Geologic Time

If we examine the fact that the amount of water has remained constant over the life of the earth and that the sea has never deviated more than two hundred meters from its present value, we recognize that damaging a thing this old is somewhat easier to imagine than it is to accomplish - like invading Russia.

Carbon dioxide, the current output from burning fossil fuels, is building up in the atmosphere at a frightening pace, enough to double the present concentration in a century. However, on the scales of time relevant to the earth - geologic time - the earth has gone through far more drastic changes and always returned to a kind of equilibrium. The sea has an immense capacity to store carbon dioxide and has done so several times over its history. The sea has risen and fallen particularly vigorously over the past million years as a result of ice-age glaciations. Glacial episodes follow the same pattern of gradual cooling, followed by abrupt warming back to conditions similar to todays. This geologic record suggests that climate is a profoundly grander thing than energy and that climate ought not to concern us too much, as we do not have as much control over it as we may imagine.

Synopsis note: Nature does not care whether or not humans survive into the future and we shouldn't equate our survival with the earth's survival.

Ch 3 - Jungle Law

An example of humans always opting for the cheapest fuel is a review of the 2000-2001 California energy crisis. This example of human greed and concentration on short term interest evolved from a flawed theory that long-term energy contracts artificially inflated prices and should be discouraged. The result was short-term arbitrage manipulation, price fixing, and load misrepresentation, megawatt laundering across state lines, withholding power, and finally shorting power delivery. The net result was to raise the retail power rates and reduce the overall usage of electricity for a number of the states involved.

From this example we can see that green technologies, which by definition are more expensive than non-green technologies, will not be properly competitive until the price of fossil fuels rises high enough a force a 'least cost' switch. The purpose of government assistance is not to replace the least cost solutions, but to help along other solutions until shortages increase the prices of fossil fuel technologies.

Ch 4 - Carbon Forever

Centuries from now, when people no longer use fossil fuel, carbon will still be with us. A lot will be in the air and the remainder will be circulating around the way it always has, through plants to animals and back into the air. Carbon-based fuels are extremely light, both because carbon atoms are light and because they exploit the chemical activity of oxygen in the air instead of attempting to be self-reliant. They are easily controlled by changing the amount of air getting to the flame and they naturally recycle within living things as an essential for life.

Quantum mechanics dictates that carbon fuels are the standard by which all other options are measured and, when oil begins to run out, the world will almost certainly respond by replacing conventional petroleum distillates with synthetic fuels that act like them. Part of the reason is that retooling the world economy would cost more than retooling the world's oil refineries.

The first source of carbon in synthetic fuels is likely to be coal, as it is the cheapest source by a wide margin and its price advantage will only increase. Coal will only last a few decades and will probably be replaced by biomass. At this time biomass will probably supply carbon-based fuels while alternative sources will supply energy. At the end of fossil fuel burning there will be a carbon revolution, not an energy revolution, where the present carbon dioxide buildup in the air will have ceased, gas will become incredibly expensive, but the economy will not be a green one.

Ch 5 - Pipes of Power

When fossil fuels begin to exhaust themselves, the price per unit of nonfossil energy delivered electrically will become cheaper than current fossil fuel production - 70% of electrical energy is now supplied by fossil fuels.   Electricity will acquire a life of its own and supplant its fossil fuel parent as the dominant energy industry.

The biggest problem with electricity is storing it until needed. This is the primary problem with solar and wind energy. The best energy storage technology at the moment is water pumping — hydropumping facilities buy electricity off the grid when the price is low, pump water uphill until the next day when the price is high, then release the water to generate electricity for sale.

Ch 6 - Inspiring Mammoths

Nuclear reactions present two serious problems that set them apart from all other energy sources: 1) The waste processes remain radioactive for very long times, and 2) the explosions they facilitate are a million times more powerful than those of dynamite. The immediate health threats nuclear energy poses are scary, but surmountable.

Nuclear fuel is fossil fuel, and it's limited just the way coal, oil, and natural gas is. With current uranium consumption practices, the exhaustion will happen between one and two hundred years from now. However, by the time the coal runs out the world will probably have extended the useful life of the nuclear fuel resources in the ground to about twenty thousand years by embracing breeding reactor practices.

While the breeder reactor is much more dangerous than current technology, two side benefits are 1) the production of cheap electricity from spent fuel rods and 2) the elimination of most of the nuclear waste during the processing of these fuel rods. Once the thousand year storage period has passed the pure fission-product waste can be spread over the ocean with no danger of increasing any radiation levels beyond normal.

Ch 7 - Calling All Cows

There's a lot of energy in manure. However, it couldn't provide more than 12% of our energy needs, even if we could collect it all. Therefore, it will probably not be a significant energy factor in the future. Growing plants for energy will compete with farming for food and therefore will probably not be a factor in the future.

The most probable natural energy source is likely to be microalgae grown in seawater. They are difficult to farm and by the time they are possible carbon, rather than energy, will be the expensive commodity. Therefore, this possible source is not a likely future option.

Ethanol will probably not be a major component of transportation fuel exactly because of its carbon inefficiencies. Whether or not microbes can profitably render cellulose into fuel matters because cellulose constitutes about one-third of all plant dry biomass and cellulose is deliberately designed to be difficult to digest.

Ch 8 - Trash Ash

Trash and trash dumps contain a great deal of carbon, however, it is wholly inadequate for supplying the world's energy, thus it's potential to the energy future will be as a carbon source, not an energy source. In this regard trash can be used, along with carbon, to yield synthesis gas when oil and natural gas - currently a cheaper source of fuel - runs out.

However, burning carbon to completion isn't profitable, so incomplete burning will have to suffice. The poisons released by the incomplete burning of trash are legend, but the worst of them is ordinary soot, which contains a witch's brew of complex hydrocarbons. Natural environmental processes will eventually render escaped pollutants harmless, but not necessarily quickly; which is why nearly all governments regulate incinerators.

The burning of trash leaves behind exotic and poisonous metals, already becoming highly regulated with regards to batteries and computers. Unfortunately, this imperative to remove metal from trash is fundamentally incompatible with battery proliferation. Present-day searches for ever-better batteries are, as a practical matter, searches for ever-more exotic metals to put in them.

Thus trash — the stuff nobody cares about, the as-yet unsolved problem that vexes mayors, eats tax money, and blights the countryside — is likely to constrain the energy future in two important ways. One is to limit the price of transport fuel by constituting a large source of cheap carbon. The other is to disadvantage electric cars by causing their batteries to be declared toxic waste, whether or not they actually are, and banned.

Waste generation is a fundamental aspect of life, and the only kind of waste not poisonous to the environment is carbon dioxide.

Ch 9 - Viva Las Vegas

The drive from Los Angeles to Las Vegas is desolate, and exhausting. However, it is the dryness, lack of cloud cover, absence of trees, and copious sunshine that make it optimal for siting solar power plants. The Mojave is also the only desert in the world endowed with lots of power lines and close proximity to large, affluent metropolitan areas. Accordingly, the first great world city likely to become solar powered when fossil fuels begin to flag is Los Angeles.

Solar power has a special place among potential future energy sources, being extraordinarily abundant. Wind energy should properly be categorized as solar energy, because the reason wind blows at all is that the sun's heat makes it do so. Wind can also be harvested with simple turbine technology that's about half as expensive per given amount of power as a comparable solar facility. However, sun and, particularly, wind are capricious forms of energy. Wind farms generally run about 25% of their full capacity. For this reason energy from the wind and sun can't become genuinely competitive until facilities capable of storing large amounts of the energy they harvest for later use are built.

The most important of the many alternatives to covering the globe with hydroelectric lakes is storing energy as heat. Thermal storage has an interesting history. Originally proposed as an alternative to Hydropumping for leveling loads on nuclear reactors, molten salts have been developed as a storage fluid for heat in newer solar energy plants. This promising process has only one downside - the concept of entropy; when we try to retrieve the energy with a steam turbine, we find we can only get about one-third back - dumping the rest into the environment through cooling towers. Solar thermal power plants don't have this difficulty because they collect the sun's energy as heat in the first place, but other kinds of solar and wind plants make electricity directly, so storing their energy as heat is much less straightforward.

Nuclear energy is so politically incorrect at the moment, but it's a proxy for natural gas - slightly cheaper at the moment, but not enough to matter. Nuclear energy focuses its energy so that moderate sized plants can deliver a large amount of energy.

The sun is factually a large nuclear reactor in space, transmitting its heat through radiation. The price we pay for this transportation system is that solar energy collectors require huge areas to function in and will likely become an environmental issue as fossil fuel depletes.

This contest between land use and nuclear fission is one reason solar energy is unlikely to supplant nuclear energy as the most important source of electric power in the world after coal runs out. Another is that solar energy will have great difficulty falling in price sufficiently to match nuclear energy's cheapness. However, The American Southwest, Western Australia, northern Africa, and the Arabian peninsula will likely be powered by the sun after the coal is gone.

The most likely future for solar energy is to serve as an insurance policy against the problems that may arise with nuclear power.

Ch 10 - Under the Sea

Humans will never live at the bottom of the sea, because it is too hostile an environment. However, it will become an increasingly important part of the world's economy as fossil fuels deplete. Beyond the oil and natural gas below the oceans, the ocean bottom will be important as a source of geothermal heat and a place where we can store things; one that won't conflict with human land use. The robot will be the facilitator of this economic rise.

High-technology gadgets tend to drop in price; at the same time the declining availability of fossil fuels will spur robot development and reduce prices to the extent that there is likely to be a robot revolution in the same way the collapse of semiconductor memory prices precipitated computer development in the 1980's.

People would operate these robots like computer games today (or as children did in the book Ender's Game by Orson Scott Card - *synopsis note*). A present-day example is military drones, which may shortly be the size of a bee.

By far the simplest way to store energy under the sea is by bubbling compressed air into tanks or bags. An enormous amount of energy would be required to compress surface air to this density for storage, but we would get it all back simply by reversing the process and driving turbines with the high-pressure air. All the energy in Lake Mead could be stored in tanks measuring about two kilometers on each side - much smaller than Lake Mead itself. This is a more practical solution to energy storage than is storing it in underground caverns. At present the entire underground natural gas storage capacity of the United States has a volume twice that required to store the energy of Lake Mead.

The engineering technology of moving and recovering the energy is not beyond our current knowledge, but the project is huge and expensive and extensive undersea exploration probably won't dawn until sometime around the turn of the next century.

Ch 11 - A Winter's Eve

The author's telling of how a returning businessman views and reacts to his environment 200 years into the future. A fitting summary of all the different complexities discussed in previous chapters.