

How do we satisfy our need for energy, and sustain our environment?

Energy usage has increased exponentially over recent time. Since 1971 there has been an unprecedented increase in global demand from 6 billion tonnes of oil equivalent, to 12 billion in 2008, that's a 100% increase in the space of 37 years. This has helped fuel price volatility in the energy markets over the past few decades, most recently oil prices in 2008 shot up to \$150 per barrel. There is also the matter of which direction the more efficient energy production goes in. Put simply; is it a fossil fuel future or a non-fossil alternative. The interdependency of nations on each other for both supply and demand of energy needs to be harnessed to bind the world together for global cooperation. Politics can make or break our sustainable energy future. Coping with all of this and the preservation of the natural environment is simply the world's greatest challenge.

Fossil fuels have been the base of human existence and it is very hard to see a way in which consumption of these non-renewable resources could be eradicated. Instead the focus is on ever increasing efficiency, and ever declining emissions. It is critical that we determine how imminent the decline of global fossil fuel resources are, and where the point of 'peak production' will fall. With a plurality of total primary energy supply (TPES) of 36%, the first consideration is oil. As definitions vary, assume that 1 barrel (of oil) equals to 42 U.S. gallons. In 1900 global output reached 150 Mega barrels per year. That same volume is now extracted in just two days. With these levels of consumption, the inevitable permanent downturn in global output of oil will start sooner rather than later.

It is nearly impossible to predict because there are so many potential variables. A group of economists in the 1980's, came to the optimistic conclusion that the commanding role of prices, unceasing human inventiveness and the surpassing power of technical fixes would mean that no natural resource (and in particular oil), is an unstoppable determinant of the fate of civilization. In particular, the future of the satisfaction of our energy needs relies on human inventiveness.

There is a constant pool of new ideas and enterprise for energy production which aim to point the way to the future of fossil fuel usage. Many of these are on an inevitably small scale and are not viable, but some have a great deal of potential on the mass market. One such potential energy future for fossil fuels is carbon capture and storage (CCS). In terms of long-term aims, it ticks all the right boxes, bringing increased efficiency and significantly fewer emissions which would help sustain the environment. In essence though the process involves the liquefaction of CO₂ and transportation of it into long-term storage and where possible to displace known methane and oil reserves which could then be more easily extracted.

The process is costly, estimated to cost an extra 20p kWh⁻¹ or an additional 40-50% of today's average costs. But it is the price of clean, efficient energy production technology that can give coal-fired power stations a breath of fresh air. One 1GW coal fired power station, like Ironbridge in Shropshire, is equivalent to a wind farm covering approximately the size of Dartmoor (953km²), which would be massively more expensive to construct and a very inefficient use of land especially in densely populated countries like the UK where density is 246/km².

Coal when burned is the dirtiest of fossil fuels, but this is counteracted by the large reserves still available. Coal's future is thus not fundamentally a matter of resource availability or production cost but one of environmental acceptability. Hence the development of 'clean coal technologies' (CCT) of which CCS is one. Others of notable significance include pre-combustion coal washing and electrostatic precipitators, both have

the intent of increased efficiency with lower emissions. But perhaps the most favourable CCT is coal gasification.

In an integrated gasification combined cycle plant, coal is not directly combusted, but instead reacts with steam and oxygen to form a 'syngas' containing carbon monoxide but the vast majority hydrogen. This is the burned in the normal way to produce steam to drive a turbine and produce electricity. There is no storage, no transportation and very close to zero emissions, thus it is seen by many as the route to sustainable energy production.

Under the broad term 'non-fossil futures' there are three main sub categories, renewable, biofuels and nuclear. 'Renewables' has been the buzzword of the twenty first century and has been deemed by many to be the only way in which increasing global demand for energy can be met whilst preserving the environment.

A combination of very large potentially recoverable fossil fuel resources, very efficient energy conversions and very low energy demand, would make it impossible for a fossil-fuelled global society to exist much longer than a few hundred years. The very obvious alternative, renewables, comes with a very obvious problem, the low energy densities of these natural resources compared to fossil fuels.

The greatest renewable potential in terms of energy density is solar energy. Solar radiation at the top of the earth's atmosphere measure 1347 W/m^2 , commonly known as the solar constant. The global mean of solar radiation absorbed by surfaces averages at 168 W/m^2 . Existing techniques of solar energy conversion allow us to convert densities as low as $20\text{-}60 \text{ W/m}^2$. This is the highest average performance of any renewable resource, not forgetting of course, that solar energy is indirectly harnessed in photosynthesis of plants which can be used to manufacture biofuels. To give a sense of scale to this, an average household uses between $20\text{-}100 \text{ W/m}^2$.

The technology most used globally is likely to be central solar power systems (CSPs), which see solar radiation concentrated to generate superheated steam to drive a conventional turbine. They can be combined with conventional fossil-fuelled generation to cope with days with low sunlight and peak demand. Conversion efficiencies range from $20\text{-}30\%$, with peak power densities of 60 W/m^2 of collecting surface. Solar energy is a very real and economically viable option for the future, with naturally no consequences for the environment. In fact the only problem goes for all renewable energies; the transportation and potential storage, because places well-embellished with any one renewable resource are often remote.

The best locations globally for solar power are sparsely populated hot-arid areas where solar radiation is plentiful. This does mean the land is used efficiently, but the distribution of electricity from that area is likely to be costly and inefficient. Although largely fossil-fuel based, a classic example of this is the national grid in the UK. Energy is often redistributed from the North to the South of England to meet varying demand. This is, however, a very inefficient process and around 12% of electricity produced in the UK is lost in distribution partly due to this procedure.

The biggest boom in a single renewable's production was seen in wind power. The now iconic tri-bladed wind turbine is seen as a symbol of the global 'green' movement. This is perhaps surprising given the very low power densities, inefficient energy conversion and very uneven distribution in both time and space of wind as a natural resource. Add on top of this the potentially harmful ultra-low frequency vibrations, although research is ongoing.

In places averaging 450 W/m^2 , such as is seen in North and South Dakota in the USA, machines with a 50m hub height would intercept only 7 W/m^2 , and would then convert 25% of that, lose 25% of that to blade soiling and wakes and you would end up with a power output of approximately 1.3 W/m^2 . Some more optimistic figures would produce a figure a little more than double that.

The other obvious problem with wind power is the wind turbines themselves. Structures of up to 80m high and rotor diameters of 80m as well, protrude out of previously unspoilt landscapes and untouched seas. Some

may see it as an enhancement to a landscape but the vast majority see them as a visual intrusion on a much sought after vista. But when concern is about the long-term integrity of the biosphere, this becomes decidedly unimportant compared to the environmental impacts arising from fossil-fuelled generation. Certainly wind power cannot be discounted from the future of energy production, almost the exact opposite, wind power conversions will become more efficient, construction costs will fall and TPES can be ever increasingly supplemented by wind generation.

The remaining non-fossil alternatives such as hydroelectric generation, geothermal generation and the incredibly broad ranging area of biofuels, have all seen commercial applications but have lacked the large scale development of the technologies behind them. Also they often have geographically variable resources, for example hydro-electric power contributes 99% of Norway's TPES due to the natural topography of the land and rivers that flow over it. The same goes for geothermal and Iceland. One non-fossil alternative, nuclear, has had an unclear future, but it could well hold the key to environmentally sustainable power generation for the future.

14% of global TPES comes from nuclear power generation (fission, fusion, fast-breeder etc.), yet it looks set to be completely eradicated in the not too distant future. Is this perhaps unjust? The greatest obstacles nuclear power faces is public opinion, which has improved but is still not categorically in favour, and unfortunately for the future of nuclear power never will be for three major reasons. The first be pinned on two major events, the Three Mile Island accident in 1979 and the Chernobyl disaster in 1986. Although a disaster on the scale of the latter is impossible on a typical, modern, nuclear reactor it still haunts the western world and has unfortunately been the centre of so many arguments against nuclear power. The second lies in the storage of waste and the third in the political impact of nuclear production in enabling countries to build up an entire nuclear arsenal. Despite the production of no greenhouse gases, the way in which so many agree is the future of sustainable energy, and despite immense energy densities (just 1kg of uranium can produce 50MWh compared to 3kWh / kg of coal) nuclear energy has begun an inevitable decline.

Forecasts of energy futures have had a manifest record of failure so instead, more general likely outcomes, that together will enable us to satisfy our need for energy, whilst shaping a sustainable future for the environment, will be given. Most statistics for energy are soaring; efficiency, usage and new technologies. What's declining? Nuclear power stations and fossil fuel resources. These must be addressed by replacement technologies for nuclear, whether CCT, renewable or just more fossil-fuelled stations. Fossil fuel resource decline will arguably be halted by the price mechanism, but is most likely to be slowed by increased efficiency in energy conversion, the increasing usage of renewable and alternative energies.

No one knows what lies ahead, although many people pretend to. What we do know is that human reliance on energy for improving well-being will never cease and that reliance will have an ever increasing effect on the environment. There is no doubt that in twenty years, fifty years, one hundred years; the questions civilisation asks about energy will be different. Efficiency will most likely be the next buzzword, and greater efficiency means a sustained environment in the future. It is instinctive for human civilisation to eradicate inefficiencies and the overconsumption of resources, as we have already seen with the renewable boom. So much power is held by the political authorities of the world, all that is needed is the will for these technologies outlined above to become a reality today, which takes determination from today's political masterminds. We need to stop predicting and questioning our future and start working with what we've got, so that our next steps can be the first steps to a brighter, more sustainable, more efficient future.

Glossary:

TPES – Total Primary Energy Supply

CCS – Carbon Capture and Storage

CCT – Clean coal technology

Wh – Watt hours

W/m² – Watts per square meter

Prefixes:

K – Kilo - 10³

M – Mega - 10⁶

G – Giga - 10⁹

T – Tera - 10¹²

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