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Physics: saviour of the planet?

In recent years climate change has had a great deal of media coverage. Yet despite this, the people of the earth and their governments seem to be taking very little action. There is a global consensus that as time passes technology and science will help us rectify the damage we have done. The planet is relying on the next generation of scientists to clear up the mess. So the question is: Is their trust misplaced - have they set an unachievable goal - or is technology the best way forward?

At first sight it seems that science is the only way to tackle the environmental problems that have arisen from the technological revolution of the past 150 years. After all, the carbon-producing elements of our modern society are products of science so it would seem logical that by further application of our scientific knowledge we can secure ourselves a sustainable future.

There are many different emission-free ways of producing energy and reducing our dependence on fossil fuels. The vast majority of these technologies are household names: wind power, solar power and the hydrogen fuel cell are just a few. It is clear that all these methods are cleaner than fossil fuels but normally the argument against their wide-spread use is their higher cost relative to their existing fossil fuel based counterparts. Of course these technologies are not without their problems, for example their source of energy is not always present – without wind, a wind power farm is useless, as is a solar power plant on a cloudy day – normally a fossil-fuels based backup system is required.

But it is clear that there is a lot of 'free' energy around us which, if correctly utilised, could supply us with a substantial amount of carbon- neutral energy.

A good example of a method which utilises energy which is already available to us is ocean thermal energy conversion (OTEC). Some energy experts believe that this relatively unheard-of technology could become a major source of energy if it were to become cost-competitive with existing modes of energy production. As with solar power, it makes use of the energy radiated onto the earth by the sun, most of which is captured by the sea. The earth's tropical oceans absorb 1600 times as much energy as we need to supply the entire planet[1]. Most of this heat is concentrated at the surface of the ocean, falling off exponentially with depth. By pumping the deep sea water to the surface, OTEC exploits this difference in temperature (about 15°C) to power a heat engine. A heat engine is a general term for a device which uses the difference in temperature between two bodies to generate electricity. A turbine is an example, where thermal energy is used to heat water and the resulting steam is used to turn the turbine. Some OTEC systems use a liquid with a low boiling point like ammonia to turn the turbines, while others place the warm sea-water in a low pressure container causing the water to boil (the boiling point is dependent on pressure) and so turning the turbines. Because the temperature difference between the waters in the ocean is relatively small, the process of extracting energy is quite difficult. By applying Carnot's theorem it can be shown that the maximum possible efficiency achievable of converting heat into work is as follows:

Carnot formula:

$$\begin{aligned} efficiency &= 1 - T_c/T_h \\ &= 1 - 283/298 \\ &= 0.05 \\ &= 5\% \end{aligned}$$

T_c is the cold water temperature in Kelvin, T_h is the warm water temperature

Although this is quite low, the amount of energy available is so huge that capturing even a small proportion is extremely useful.

Unlike a lot of 'green' technologies, once running, OTEC can produce energy continuously. It is potentially (for our current needs anyway) an infinite source of energy. It is not dependent on the availability of oil, it produces no emissions and there is no waste-product at the end of the process - in contrast with nuclear power. There are other uses for the cool water obtained from the ocean: it can be used to air-condition buildings (directly or using a heat-exchanger) or for mineral extraction. OTEC has been tested and does work and there are several systems running profitably such as NELHA[2], an OTEC facility in Hawaii.

Thus it may seem at first sight that science has all the answers, but in fact the situation is more complex. We need to examine why it is that we do not have new green power plants appearing around the globe, alongside or better still replacing their carbon-producing relatives.

The ideas have been laid down; now we have to occupy ourselves with their implementation. We are not being held back by lack of scientific knowledge but by political and economic constraints. Essentially, at the heart of the problem is the reluctance of any individual nation to lead the way into a new, greener future. Every government, at least in principle, will agree that a greener, less polluted world is better for us all. But no government is currently prepared to make the environment the focus of its political endeavours. What we have here - on a global scale - is similar to a famous game theory thought experiment: the prisoner's dilemma.

The prisoner's dilemma[3] is as follows:
Two convicts, A and B, are arrested by the police. Because the police do not have enough evidence to convict either of them, they offer each of the prisoners a deal: if one testifies for the prosecution of the other and the other remains silent, the betrayer walks free and the other prisoner receives the full sentence in jail for the crime. If neither admits to the crime, they both receive a short sentence for a minor charge. If both betray each other, they both receive a medium-length sentence. Each prisoner must make his decision in isolation.

	Prisoner B remains silent	Prisoner B betrays
Prisoner A remains silent	Both get 6 months in jail	B walks free, whereas A spends 10 years in jail
Prisoner A betrays	A walks free, whereas B spends 10 years in jail	Both receive 2 years in jail

In this problem a dilemma arises because although cooperation is beneficial for the group, betrayal benefits one prisoner at the expense of the other. Of course, if they both get greedy and betray each other they are both dealt a substantial punishment. This can be compared to the global situation at the moment by replacing prisoners with countries. If we only consider (for simplicity) two countries we have:

	Country B acts to prevent climate change	Country B ignores climate change
Country A acts to prevent climate change	Both spend money but also both profit from end result	A has to spend more money and so its economy falls behind B
Country A ignores climate change	B has to spend more money and so its economy falls behind A	Problem slowly gets worse, until eventually both suffer

This idea works no matter how many countries are involved, in fact the more there are the worse the problem is. It illustrates how if a lone country tries to tackle the problem (properly) on its own it will cost itself a lot of money and put its future at risk. More importantly, as climate change is a global issue, the work one isolated nation does will help not just itself but the entire planet, meaning that everybody gains whereas only one nation has to pay. For example, if Russia stopped producing emissions completely it would cut the total emissions worldwide by 5.9%[4], but instead of stabilising its own environment, it would probably ruin its economy and globally its sacrifice would amount to almost nothing.
It is clear that the only possible solution is global cooperation. But world governments are unwilling to commit themselves to this; the rich and therefore dominant nations do not want to threaten their

position, whilst the poor have little control and aside from this produce such a negligible fraction of world emissions that their effect on climate change is minimal.

This reluctance to cut emissions stems from the same cause as the lack of real investment into new technologies: there is a global unwillingness to risk political and economic power for the sake of the environment.

This lack of co-operative action is inherently counter-productive and very damaging to the environment. In order to develop a realistic and effective approach to climate change, we must go beyond the simplistic assumption that technology alone has the key. Saving the environment and realistic economics are not polar opposites; they can be made to work alongside each other. Erasing our carbon footprints and repairing the damage done should not be viewed as a menacing cost but as a joint economic and scientific challenge with the goal of improving the standard of living for future generations.

There have been several ideas on how to utilise our capitalist economic system to help cut emissions. For example, carbon trading schemes have been introduced: countries are allocated a certain level of permissible emissions and when they emit more they must buy 'carbon credits' from countries which emit less. Such schemes are excellent in theory, creating a cap on global emissions and giving an economic incentive to go green. But they are utterly useless if not implemented globally because they will hurt the economies of those who stick to the scheme as they will be unable to compete with the countries which have no ecological obligation. We have arrived back at the prisoner's dilemma and illustrated how lack of compromise and co-operation between nations is the true problem behind the escalation of climate change.

Economics is often cited as an obstruction to environmentally-friendly development. For example, a frequently-heard excuse not to build greener power plants is their cost. We are told that until their cost becomes comparable to existing alternatives they are not economically viable. The answer here is not to expect science to lower costs miraculously but to tax the polluting technologies heavily, thus making the green alternative cheaper and so more profitable. The money generated from this tax can be used in subsidising green technology, making it possible to operate profitably.

Recently the Stern report estimated the cost of *not* tackling climate change to be £3.68 trillion[5]. The need to justify action on climate change by means of quantifying it financially may be a sad reflection on our capitalist society, but if this is what it takes to bring about change then we should be prepared to look at environmental problems in terms of economics. It has been suggested that the price of effectively tackling climate change could be paid by sacrificing a year's worth of global economic growth[6].

It is clear that physics must play an important role in safe-guarding our planet against the potentially disastrous effects of climate change. But it is unlikely to succeed unless politicians and governments adopt policies which encourage change. Heavy taxation must be imposed on environmentally unsustainable forms of energy production, thus allowing new, greener alternatives to compete economically. But above all, global co-operation is essential in guaranteeing a sustainable future for us all. The next chapter in world history is not about whether physics can protect the earth, but whether it is allowed to do so.

1 http://en.wikipedia.org/wiki/Solar_power

2 http://www.nelha.org/

3 Kuhn, Steven, "Prisoner's Dilemma", The Stanford Encyclopedia of Philosophy (Fall 2003 Edition), Edward N. Zalta (ed.)
http://plato.stanford.edu/archives/fall2003/entries/prisoner-dilemma

4 United Nations Data Division
http://mdgs.un.org/unsd/mdg/SeriesDetail.aspx?srid=749&crid

5 Hinsliff, Gaby, "£3.68 trillion: The price of failing to act on climate change", The Observer
http://observer.guardian.co.uk/uk_news/story/0,,1934381,00.html

6 Seager, Ashley, "Cost of saving the planet: a year's growth", The Guardian
http://environment.guardian.co.uk/climatechange/story/0,,1883753,00.html