Energy.

With the current focus on climate change and resource sustainability its interesting to think more deeply about the sources and uses of energy on earth.

Fossil fuels. Fossil fuels represent 85% of global energy generation. General opinion is shifting towards the view that fossil fuels are unsustainable because, a) there is a finite endowment which is being exhausted, b) alternative energy will be more economical, and c) the climatic consequences of fossil fuel consumption are too high. Whether one agrees or not with these arguments depends on one's point of view, time horizon, and economic interests.

It will take a long time to exhaust the current endowment of fossil fuels. The practical supply is much dependent on the costs of extraction and processing and the willingness and ability to pay these costs. Given sufficiently high energy prices, the feasible reserves increase and move the point of depletion further and further away. However, the question is one of time horizons. Given a sufficiently long horizon, we will exhaust the resource. The time it takes to produce fossil fuels is too long, much longer than the time it takes to extract, process and burn it. Since reserves are finite, however large they may be, and we are net destroyers of that resource over time, in fact at any given time, the resource must eventually be exhausted, not in the limit but at some finite time horizon. The impact of extraction alone, needs to be considered, not just the waste products of consumption. What does a planet denuded of fossil fuels look like, what is its geology, geography and ecology? One possibility which may not have been given much consideration, and perhaps with good reason, is to find ways to replace the fossil fuels more quickly than they are depleted. Is this cost effective? Is it possible or practical? Are there better alternatives?

What are the viable alternatives to fossil fuels? Wind, solar,

hydro and nuclear power are the main alternative sources of energy. Wind and solar power suffer from inconsistent supply. Apart from generation costs, they are also dependent on storage costs. Batteries, capacitors, flywheels and weights can be used to store energy depending on how long it needs to be stored. Wind power is a sustainable and renewable energy which is a viable alternative to fossil fuels. It currently represents about 5% of global power usage achieving grid parity in Europe in 2010 and in the US in the near future. That said, grid parity is of limited use as a measure of comparison. Even then, the impact of wind power is not fully understood. What happens to the frictional properties of the earth's surface under the proliferation of wind turbines? Solar power, another sustainable power source currently provides some 2.8% of global energy usage. The International Energy Agency predicts that by 2050, solar power would be the dominant source of energy. In a way, solar power has parallels to the energy transformation process in the production of fossil fuels. Fossil fuels are organic stores of chemical energy stored in the ground which trace their energy source to photosynthetic capture of solar energy millennia in the past. Hydroelectric power is still small scale and largely dictated by the physical geography of the earth.

In the end, there are only so many sources of energy. Nuclear energy powers the sun. Light energy brings that energy to the earth where photosynthetic plants convert the energy into chemical energy which is then stored in the earth's crust until it is extracted in the form of fossil fuels. Heat energy from the sun also powers convection resulting in winds that power turbines. Weather pulls water from oceans to high ground where they accumulate. On their return to the sea, the gravitational potential energy is converted into kinetic energy which is harvested by turbines and generators into electrical energy. In large scale, there is but one single energy source: the nuclear energy of the sun. All this planet can do, is harvest it and recycle it. Failure to harvest sufficient energy will lead to an eventual catastrophic deficit. Recycling helps mitigate short term

deficits.

Harvesting of sunlight can take several forms. The oldest is photosynthesis. Plants form a part of our solar panel array. The chemical energy they accumulate has to be processed to form combustible compounds such as biodiesel, ethanol or methane which can be burnt for fuel. There are practical, engineering reasons why currently, biofuels may not be efficient alternatives to fossil fuels, but theoretically, they can be. Photovoltaic cells, and concentrated solar thermal power is another way of harnessing the sun's energy. How they differ from fossil fuels, is time. Fossil fuels are millennia of inventory, inventory that we are now drawing down. As we do so, we also release the carbon captured when the energy was stored.

An alternative to harnessing the power of the sun, is to replicate that power source on earth. This is nuclear power, which currently represents 10% of total energy production. Nuclear power is potentially inexhaustible since as long as there is matter available for conversion, there is power. The issues around nuclear power are safety and cost. On the basis of cost, nuclear power ranks well, on a total basis including capital costs and operating and maintenance costs with the capital costs being the greater share by far. Nuclear power is almost as cheap as coal and far cheaper offshore wind and solar, both photovoltaic and thermal. The consistency of supply is not even in question. The main issue with nuclear power, is safety. The memory of Three Mile Island, Chernobyl and Fukushima remain with us. Despite a low death toll, these nuclear accidents generated a disproportionate public reaction. There are good reasons to suspect that the long-term effects of these accidents, beyond the immediate death toll, are not yet fully understood. However, the low cost and energy efficiency of nuclear power makes it a viable source to pursue. What is needed is to improve safety with a view to large scale deployment. Reactors based on alternative fuels to uranium which can be dangerous and weaponized could be found such as thorium.

Yet another alternative solution to our energy problems is to

either produce the energy off-planet and send it back, something called space-based solar power (SBSP), or to relocate energy intensive industry off-planet.