forum for the future
action for a sustainable world

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# investments to combat climate change – exploring the sustainable solutions

Contribution of Forum for the Future to the London Accord

The London Accord $CO_2$

# contents



Forum for the Future - the sustainable development charity - works in partnership with leading organisations in business and the public sector. Our vision is of business and communities thriving in a future that is environmentally sustainable and socially just. We believe that a sustainable future can be achieved, that it is the only way business and communities will prosper, but that we need bold action now to make it happen. We play our part by inspiring and challenging organisations with positive visions of a sustainable future; finding innovative, practical ways to help realise those visions; training leaders to bring about change; and sharing success through our communications.

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# 1 executive summary

This paper has been prepared by Forum for the Future as part of its contribution to the London Accord’s collaborative research. It explores some of the barriers to greater investment in clean technologies and looks at investment in new technologies from the point of view of their overall impact on sustainable development.

The need for investment in measures to combat climate change is clear. The Inter-governmental Panel on Climate Change has provided scientific evidence that climate change is happening and that increasing levels of carbon dioxide created by human activity are a fundamental driver. The Stern Review has shown that the economic costs will be much greater in the future if we fail to take urgent action against climate change now.

In addition, models such as the Princeton Wedges have illustrated how known technologies could deliver the reductions in greenhouse gases required. And further work on abatement cost by McKinsey has indicated that the reductions can be achieved by deploying technologies at a reasonable cost (40 Euros per tonne).

However, a number of practical problems arise, including -
(a) The carbon price is currently much lower than 40 Euros a tonne and does not send the right signals to the market to incentivise investment
(b) The choice of measures to combat climate change does not always take account of wider sustainability issues.

The report focuses primarily on this second area. Wider sustainability issues matter in selecting options to combat climate change as, apart from being important in themselves, they are also often likely to be material to the commercial viability of an investment. The five capitals framework provides an outline for thinking through the impacts of technologies on people and the environment. Natural, human, social, manufactured and financial capital all have an important place in an assessment of the value of options available.

Studies by the Millennium Ecosystem Assessment and by the United Nations Environment Programme have highlighted concerns over the depletion of natural capital, with more than half of the “ecosystems services” provided by nature being used unsustainably. The choice of options to combat climate change needs to take account of impacts on water, pesticides, land use, deforestation and many other aspects of natural capital. Also, new technologies themselves may be vulnerable to the impacts of climate change.

Equally important is an assessment of the impacts of specific climate change solutions on people and communities. At the macroeconomic level, the approach to climate change solutions in developing countries, whether new technologies or avoided deforestation, will be especially critical to the success of global dialogue on climate change. The question of social equity in carbon emissions will be a critical component of discussions on the options that should be deployed. At the microeconomic level, the productivity of labour and the support of local communities will influence the success of the investment options.

In principle, the greatest global public good will be achieved by the measure or technology that optimises the outcomes over the five capitals, taken together. In practice, there are many reasons why the solution will not be optimal -

- Inadequate identification of the issues
- Difficulties in measuring the impacts
- Challenges in incorporating the value of impacts into decisions
- Maximising individual capital at the expense of global capital, leading to sub-optimal outcomes for both.

The following key themes emerge:

- Investor interest in options to combat climate change is growing, as evidenced by the level of investment in specific cleantech funds and by the launch of many climate change-themed funds[1]. The London Accord will play an important part in developing this interest.
- There is still much too little investment to meet the challenge of climate change.
- Models suggest that existing technologies can be deployed to deliver the solutions we require.
- The impacts of different options on wider sustainability need more sophisticated analysis. This is not only because this will ensure that they are commercially viable in the longer-term. It is also because the impacts on natural capital, people and communities will affect whether a particular option will in fact deliver the carbon emissions reductions expected.

And the principal recommendations arising are:

- In order to manage risks and develop opportunities, investors should
  - recognise the economic and financial imperative to combat climate change;
  - develop tools to assess how climate change might impact the economy and investment portfolios, highlighting the need to invest in clean technologies;
  - require rigorous research of sustainability impacts for all investment options to combat climate change, and develop criteria for investment that include both social and environmental safeguards;
  - undertake further research into the challenges posed as new technologies scale up, and how to address them;
  - actively consider the construction of a diversified portfolio of investment options to combat climate change, possibly by means of emerging index products.
- In order to incentivise increased investment in measures and technologies to combat climate change, Governments should
  - improve regulation to require higher technical standards for energy efficiency, particularly for buildings and vehicles;
  - consider tax incentives for funds designed to invest in options to combat climate change, provided they incorporate sustainability criteria;
  - further explore how to make more constructive links between the interconnected agendas on carbon and international development, particularly on forestry;
  - ensure that clean technologies are viewed as part of an innovation and competitiveness agenda, enhancing skills and opportunities.

[1] Investor awareness of the materiality of this issue across their portfolios and in all sectors is also growing (as seen, for example, in commitment to the Carbon Disclosure Project) but this paper focuses particularly on clean technologies.

# 2 introduction

This paper has been prepared by Forum for the Future as part of its contribution to the London Accord's collaborative research. It explores some of the barriers to greater investment in clean technologies and looks at investment in new technologies from the point of view of their overall impact on sustainable development.

It is divided up into four sections. In the first section we explore whether traditional financial analysis is fit for purpose in allocating capital towards the energy technologies that will generate the optimal return on capital.

In the second section, we consider broadly how clean technologies affect, and can be affected by, social and environmental factors, and we discuss a framework for considering these aspects.

The third section looks in more detail at the wider social and environmental impacts of various technologies, which will affect their financial viability and long-term sustainability but may not currently be factored into investment decisions.

The final section provides some conclusions and recommendations.

# 3 allocation of capital to climate change solutions

## 3.1 The need for investment in climate change solutions

***The need for investment in measures to combat climate change is clear***
There is growing recognition around the world of the urgent need to invest in new technologies and processes that will enable global society to reduce its carbon emissions. The members of the Inter-governmental Panel on Climate Change[1] have presented a clear analysis of the science, and with each report the IPCC underlines the increasingly urgent nature of the challenge. The Stern Review[2] highlighted how the impacts of climate change translate into a need for action on economic grounds.

***The technical potential for renewable technologies is significantly greater than current use, and the theoretical potential many times greater***
Table 1 below shows estimates of the current use of renewable technologies worldwide, the potential using existing technologies and the theoretical potential.

**Table 1**: Summary of the renewable resource base

| Resource | Current Use (EJ) | Technical potential (EJ) | Theoretical potential (EJ) |
|---|---|---|---|
| Biomass energy | ~ 50 | 200-400 (+) | 2,900 |
| Hydropower | 9 | 50 | 147 |
| Solar energy | 0.1 | >1,500 | 3,900,000 |
| Wind energy | 0.12 | 640 | 6,000 |
| Geothermal energy | 0.6 | 5,000 | 140,000,000 |
| Ocean energy | NA | NA | >140,000,000 |
| Total | ~ 59 | >7,600 | >144,000,000 |

Source UNDP World Energy Assessment 2000

***Models have indicated the technical feasibility of the necessary transformation***
The Princeton "wedges" model[3] highlighted that emissions could be stabilised through application of a range of different investment options. A more recent model presented by WWF in its Climate Solutions report[4] outlined the composition of a portfolio of sustainable energy solutions that could deliver the projected global demand for energy while at the same time keeping greenhouse gas emissions below the level (400 $CO_2$e ppm, in their view, after a short term rise above that level) likely to trigger dangerous climate change.

These two different models are encouraging in one way because they show that it is technically feasible, given existing technologies, to construct a portfolio of assets that will meet the combined needs of growth and carbon reduction. That is clearly massively important. But they also highlight substantial challenges in actually delivering the required investment in these new technologies, and reduced investment in traditional carbon-intensive technologies. This will only take place if there are adequate incentives in place.

***The incentives to make the changes are currently inadequate***

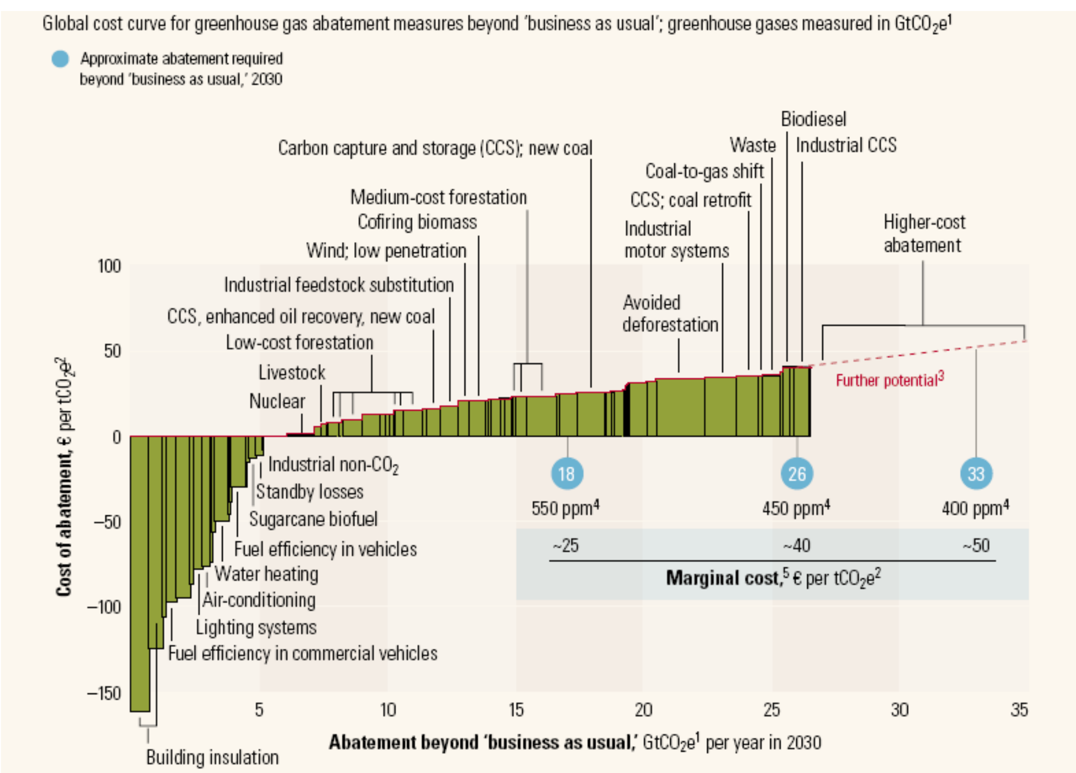
Investment in new clean technologies has increased substantially in recent months, supported by the economic arguments put forward in the Stern Review[5], an apparent firming of government policies on carbon emissions targets, and growing consumer awareness of climate change. However, it is clear that investment on the current scale will not deliver the carbon reductions required, especially not over the time-frame needed. Stern, for example, suggests that the major investment in transformation to a low-carbon economy has to take place in the next ten to fifteen years if we are to avoid dangerous climate change. In WWF's analysis[6], the time-frame is five years.

So what is currently preventing measures, including clean technology investment, being adopted on the scale required?

***Abatement can be achieved at a cost lower than the economic cost of inaction***

The "cost" of new technologies compared with traditional technologies such as oil and gas is often cited as the principal barrier to investment. Until these costs come down, it is argued, there can only be limited investment. But work done on the costs of abatement by McKinsey and Vattenfall[7] has shown that there are many measures that can be taken at a reasonably low cost, with almost 6 gigatons of carbon reduction available at zero or negative net lifecycle cost. McKinsey (using an assumption of 450 ppm, compared with the 400 ppm figure used by WWF) estimates that the marginal cost associated with the level of abatement required is 40 Euros per ton of $CO_2$ equivalent. Many measures can be implemented at or below this cost.

**Figure 1**: Global cost curves for abatement measures




Source: Vattenfall

## 3.2 Barriers to investment in climate change solutions

### 3.2.1 Carbon prices do not send the right signals to the market

The price in the carbon market is currently significantly lower than 40 Euros a tonne and projections, even under Phase II, where the tighter allocations of emissions allowances are likely to create actual shortages and push up prices, do not show it rising to that level within the next 5 years. The incentive for investment in low-carbon technologies is therefore substantially reduced. Without a market price (whether existing or anticipated with some certainty for the future), financial analysts do not have the tools to value and incorporate the wider economic costs of climate change.

***Investors need greater confidence in the long-term regulatory framework***
Governments' announcements of targets for carbon reductions send clear signals to investors, but only if they are known to be robust and if governments' commitment to the targets is unflinching. To date, that assurance has not really been sufficiently convincing. If the market price of generating greenhouse gases were clear and unambiguous to investors (whether through binding targets set by governments or through a robust carbon trading scheme to which all major worldwide carbon-emitting nations subscribed) and if that price truly reflected the actual damage being done, then arguably investment in clean technologies would be much further advanced.

***Investors need to factor the economic costs of inaction into their analysis***
In the absence of clear and adequate market signals, investors do not have straightforward incentives for taking a long-term view. The investment research houses participating in the London Accord have shown an admirable appetite for more sophisticated analysis, but this is only the start. If the market failure of climate change is to be corrected, this will require a lot more analysis of the real long-term costs of doing too little too late and development of methodologies to incorporate these scenarios into decision-making on investments.

### 3.2.2 It is difficult to change consumer and business behaviour, even when there is clear financial benefit

The abatement cost curves illustrate very clearly that reducing carbon emissions is not all about cost. Many measures that can be taken in fact have a negative cost – for example, increased fuel efficiency, insulation improvements and improved lighting systems. McKinsey[8] estimates for example that a quarter of all abatement potential at a cost of 40 Euros per tonne involves efficiency-enhancing measures, particularly in the buildings and transportation sectors. And WWF estimates that efficiencies could reduce projected demand for energy by 39% annually[9]. But the costs saved by implementing these efficiencies are not currently a sufficient incentive for action.

### 3.2.3 The choice of measures to combat climate change does not always take account of wider sustainability

While climate change is understandably the overriding concern at present, we are in danger of making investments in unsustainable and commercially unviable options if we focus only on the immediate impact on carbon and fail to recognise the wider sustainability of the abatement measures being proposed. While this inevitably increases the complexity of implementing measures to combat climate change, it is the only approach that will deliver the long-term solutions we need. No energy source will be free from negative impacts, but by understanding the impacts in more depth investors, in consultation with other stakeholders, will be in a better position to make judgements on the balance of costs and benefits arising from specific technologies and how these will affect their long-term viability.

## 3.3 The Five Capitals Framework

The “Five Capitals Framework” provides an outline for thinking this through. This Framework, developed by Forum for the Future, considers all aspects of the long-term sustainability of activities. The capitals are described in Box 1. Jonathon Porritt, in “Capitalism as if the World Matters”10, provides a detailed assessment of why these capitals all need to be recognized and valued.

**BOX 1 - THE FIVE CAPITALS**

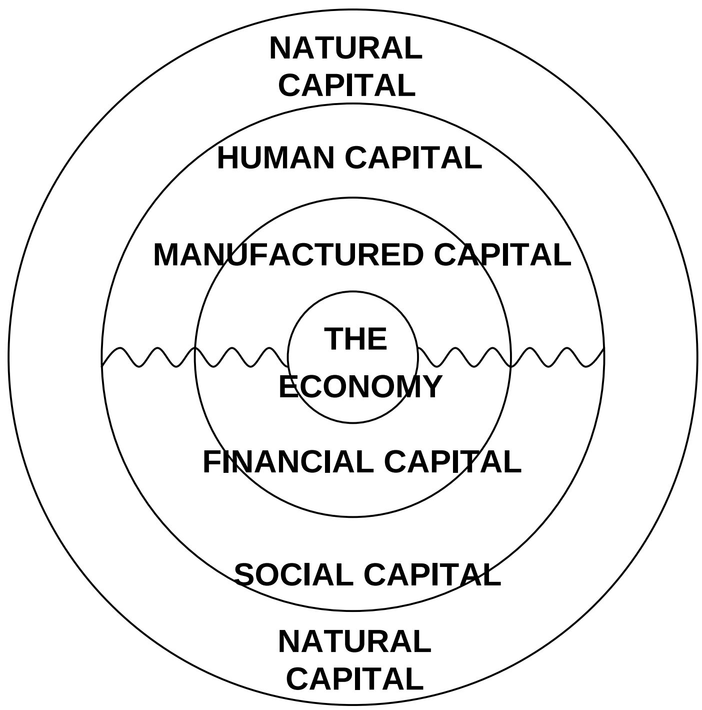
**Natural Capital**
any stock or flow of energy or matter that yields life, goods and services

**Human Capital**
health, knowledge, skills and motivation required for productive work

**Social Capital**
the value added to any activity by human relationships and cooperation

**Manufactured Capital**
material goods (tools, machines, roads) which contribute to the production process

**Financial Capital**
no intrinsic value itself but reflects the productive power of the other types of capital




***Life Cycle Analysis***
This paper aims to highlight the key impacts of each of the technologies on all of these capitals. There are different impacts at various stages of the process from raw material extraction to production to distribution to use and end-of life, so a full “life cycle analysis” is required. When investment options to combat climate change are being compared, there is often an incomplete understanding of the impact on the five capitals at each stage of the life cycle, so the comparisons may often be flawed.

The remainder of this paper considers how measures to combat climate change might have an impact on, and be affected by these five capitals during their life cycle.

# 4 new technologies and the five capitals

This section looks broadly at how measures to combat climate change will affect, and be affected by, the five capitals outlined above. Section 5 will consider specific technologies.

## 4.1 Natural capital

As a global society, we depend on certain "services" delivered by nature, of which climate regulation is only one. Others include clean water, clean air, pest regulation, disease regulation, soil and wild fish stocks. This is natural capital.

***Recent studies have highlighted the dangerous depletion of natural capital***
Both the Millennium Ecosystem Assessment (MA)[11] in 2005 and the Global Environment Outlook report by the United Nations Environment Programme in 2007[12] noted that, of 24 ecosystems services analysed, more than half were being depleted. WWF's One Planet Living campaign[13] highlights the fact that we are currently using up the earth's resources at an unsustainable rate.

In basic terms, we are currently living off and depleting the earth's capital, rather than living off the interest. As with financial capital, we will reach a point where we no longer have any capital to play with. Figure 2 shows that we went overdrawn in the 1980s and that this debt has worsened since. Figure 3 shows the different global distribution of ecological footprints and biocapacity. The Asia-Pacific segment is set to grow significantly due to the combined impact of increased affluence, higher population growth and accelerated environmental degradation.

**FIGURE 2** – World Ecological Footprint – Source: One Planet Business, WWF and Sustainability, 2006

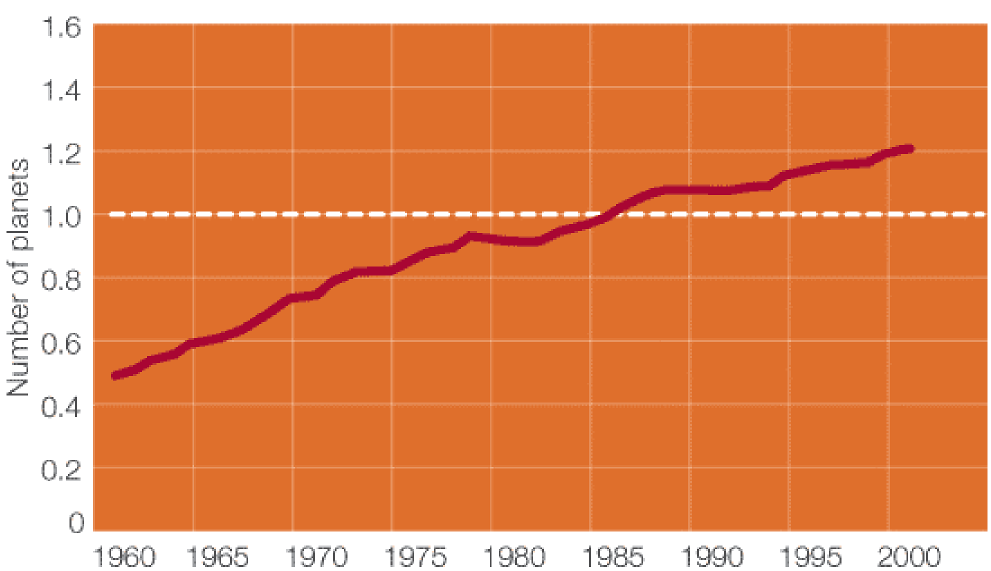
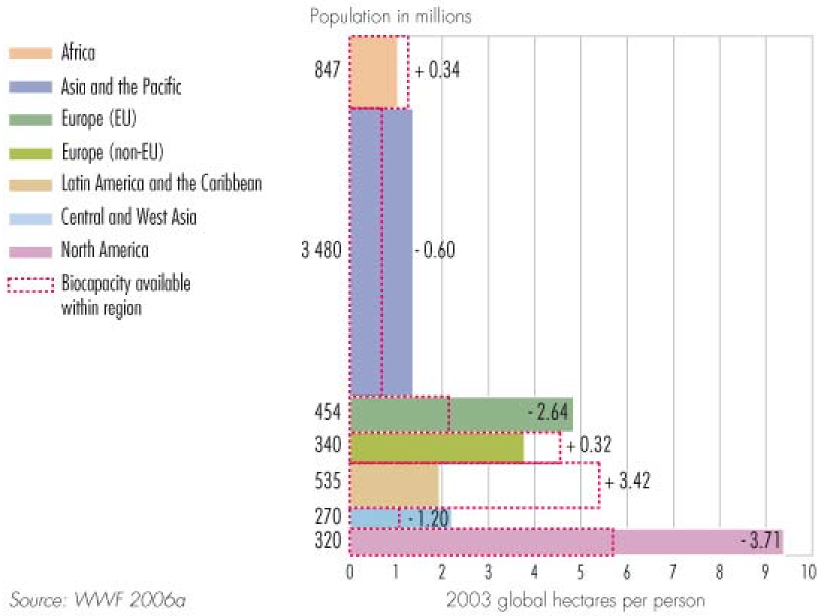


**FIGURE 3**: Ecological footprint and biocapacity by region




Source: WWF

The MA also found evidence of "non-linear" (abrupt or accelerating changes) in many of these ecosystems, with clear implications for people's health and well-being. These included emerging diseases, water quality, climate, "dead zones" in coastal waters, the collapse of fisheries and the extreme vulnerability of the 2 billion people living in dry regions to water shortages. The MA noted that other areas not currently receiving the attention of policy-makers but which pose a significant threat to human health include nutrient pollution.

This is not just a matter of concern for environmentalists. It indicates a fundamental problem for our ability to maintain economic growth at the rate we have become used to, unless we begin to value these ecosystems services in a different way and incorporate the impacts on them more effectively into decisions on how to allocate capital.

***The choice of options to combat climate change needs to take account of impacts on water, pesticides, land use, deforestation and many other aspects of natural capital***

Many of these issues have a direct impact on the choice of suitable new technologies to combat climate change. For example, technologies that rely on large quantities of water will not be appropriate in certain regions. The increased variability of rainfall patterns and temperatures will create specific challenges. Technologies that significantly affect land use, or which further exacerbate the problems caused by nutrient pollution, will need to be carefully assessed for their impacts on critical ecosystems.

***New technologies will themselves be vulnerable to changes in natural capital***

The impact of changing natural capital on the viability of new technologies is also a critical dimension to their sustainability. Perhaps the most obvious is the extent of the technology's ability to operate in the face of a changed climate. However quickly new technologies come on–stream to enable the transition to a low-carbon economy, most observers consider it inevitable that more extreme weather events will take place. Indeed, some scientists take the view that we have gone beyond the point of dangerous climate change and that feedback loops which will compound the problem have already kicked in. So any new technologies have to be able to cope with potential weather-related shocks, including drought, floods, hurricanes and more extreme temperatures. They will also have to factor in the uncertainties of changing weather patterns.

***New technologies may incorporate specifications to reduce vulnerability; some technologies will not be viable in certain regions or under certain scenarios***
To some extent, these risks have to be managed on a project-by-project basis. For example, the design and construction of hydropower dams will need to take into account the possibility of rainfall patterns being very different from historical ones, whether to protect against mud-slides arising from heavy rain, or to cope with reduced water flow as a result of drought. Reforestation or forestry conservation programmes will need to allow for changing weather patterns in order to minimise the risk that forests will be severely affected by changing weather, reducing their effectiveness in carbon sequestration. The productivity and success of biofuels projects will be fundamentally influenced by climatic conditions in different growing regions. And wind farms will be sited where air flows are sufficient to generate the optimum power without causing damage to the infrastructure.

In summary, the risks to new technologies will be able to be mitigated through rigorous planning which reviews the expected performance of the new technologies in the context of the changing climate, and builds in appropriate design and operating parameters in the light of this data. But some technologies will be inherently more vulnerable than others.

## 4.2 Human capital

Human capital – the skills, intelligence, experience and well-being of individuals – may also be enhanced or destroyed by different options to combat climate change.

***Impacts on people need to be considered alongside environmental impacts***
Measures to combat climate change, focused on environmental improvement, need also to be seen in the context of wider impacts on people and communities, or human and social capital. There is otherwise a danger that they will be seen as irrelevant to people, or even directly counter to their perceived interests, particularly in the developing world. This could create a backlash and prevent the success of a particular technology.

***The approach of developing countries to new technologies is particularly important***
Investments in human and natural capital are sometimes considered to be in conflict, with economic growth creating material prosperity but environmental degradation. Rapid rates of growth in developing countries in recent decades have resulted in reduced poverty and increased quality of life for many of their citizens – an increase in the “stock of human capital”. This rate of growth, and the speed at which this is requiring new energy sources to be brought on-stream, is clearly a significant factor in the acceleration of climate change. One well-worn statistic is that China is currently in the process of building 550 new coal-fired power stations, and opening them at a rate of 2 a week. Some argue that poverty alleviation must come first and when people reach a certain level of wealth they can have the “luxury” of considering the wider environmental impacts of their activities. This is probably not the best route to maximising the welfare of

individual citizens or society (human and social capital) over time. Climate change is happening now and is already having an impact on poverty. Time is not on our side.

***The impacts of climate change will slow down economic growth, but the impacts on the poor will be greatest***
Weather-related shocks, including droughts, floods and hurricanes; water shortages; and heat-affected infrastructure will increasingly impose costs on governments and individuals. As the range of locations and activities that become affected and uninsurable grows, so economic activity will slow down further. However, the distribution of impacts will be socially uneven and the poor are the most vulnerable. This is for a range of reasons: poorer countries are geographically more exposed to climate extremes; more people in developing countries are in agriculture, which is very dependent on climate; poorer individuals cannot afford to adapt; and richer countries can use public money to provide adaptation infrastructure such as flood barriers.

***Economic incentives for new technologies may enhance skills and competitiveness***
Incentives towards innovation in carbon-friendly technology can generate skills and experience that will increase the stock of “human capital”. This is often seen as an area of competition between countries. Certain new technologies will be of greater benefit in terms of the overall stock of human capital, because they require more people or greater skills than the alternatives.

***The potentially higher cost of new technologies could affect incomes and well-being***
When the cost of a new technology is higher than other traditional technologies, acquisition and use of that technology could increase the cost of living or restrict access to energy to the richer sections of society. This will play out differently in different countries and the net effects on social, human and natural capital need to be carefully assessed. For example, replacement of traditional fuel-wood burning in developing countries with alternative energy systems could have the potential to increase human capital because of improved health and less time spent collecting wood, and could have a positive impact on natural capital because of the reduced depletion of the wood resource. But the up-front financial cost of the technology might prevent these capital benefits being enabled, or limited access could increase social inequity.

## 4.3 Social capital

Social capital, consisting of the networks of family, friends and communities that we can connect with and rely on, is the glue that bonds societies together. Without it, a community would not be able to function, with breakdowns in law and order and failure of social welfare support systems.

Different investment options will have fundamentally different impacts on social capital. Some of the key aspects are explored below.

***The choice of measures to combat climate change will impact on energy security and on potential sources of conflict***
For example, energy generation technologies based on fossil fuels rely on procurement from regions that are often volatile, and as these supplies become more constrained, it is possible to imagine that conflicts will arise. This likely negative impact on social capital is a very important reason to seek to diversify away from this source of energy and others where energy supply is insecure. The availability of water is another potential source of conflict that needs to be considered in the choice of technologies.

***On–grid or off-grid solutions will affect communities in different ways***

Social capital will also be fundamentally affected by how energy is delivered.  Systems that supply off-grid solutions to communities will have a different impact on social capital than large-scale on-grid solutions.  Whether each is positive or negative will be determined by factors that are difficult to predict – for example, the cost, efficiency and accessibility of the various options – and will vary in different geographies.  But this needs proper assessment in any examination of the sustainability of the options.

***The state of social capital will influence consumers' attitudes and behaviours towards new technologies or other measures to combat climate change***

Another key trend arising from climate change may be shifts in consumer attitudes, which are closely dependent on interaction within communities, and what is considered to be the norm.  A significant change in behaviour around vehicle fuel efficiency and buildings efficiency could yield significant new investment opportunities.  It is also possible that changes in public perceptions could translate into a greater demand for renewable energy.  The growth of these markets will depend on the interaction between consumers, business and governments.

***And social capital can also lead to opposition***

Some technology options already face significant protest from local communities – for instance wind farms in the UK – which can act as a severe brake on technology deployment. There may be broader societal protests against other new technologies, such as nano-engineered solar PV cells or genetically modified biofuels. An assessment of the impacts on local communities is necessary for many climate change solutions.

***Building social capital / global co-operation in combating climate change requires some degree of recognition of the need for social equity***

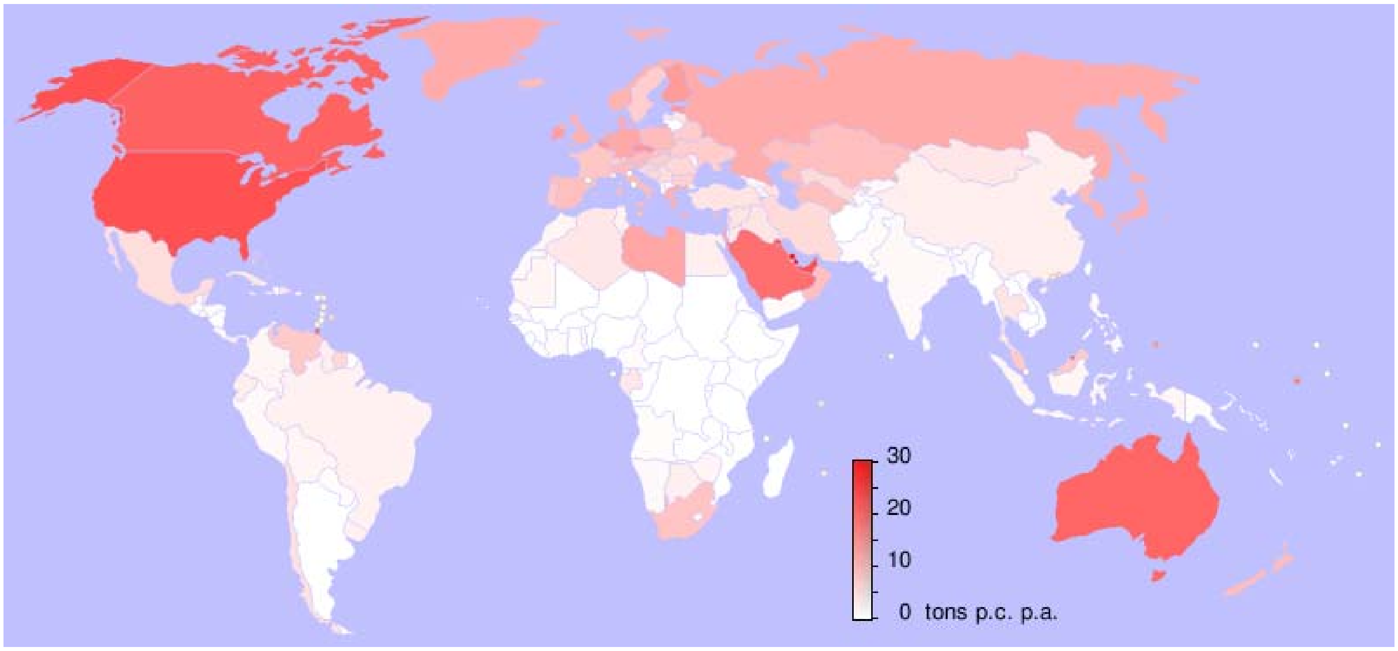
At the global level, enhanced social capital can result in cooperation, and a breakdown in social capital can result in conflict.  Much of the global dialogue on options to combat climate change, and responsibility for taking action, revolves around the question of social equity.

The current global "distribution" of carbon dioxide emissions is illustrated in figure 3.  For example, The US Carbon Dioxide Information Analysis Centre has estimated that, in 2004, the average emissions per person in the US were around 20 tonnes of $CO_2$ equivalent per year, while in China the figure is around 4 tonnes and India just over 1 tonne[2].  It is hard to avoid the argument that the industrialised countries need to demonstrate their commitment to closing that gap through investment in clean technologies.  Developing country governments are increasingly calling for compensation for the impacts of climate change on their countries' environments and economies.

Global cooperation is important for the success of individual investment options to combat climate change, because political commitment to renewable technologies will play an important part in underlining the robustness of the investment case.

[2] Some figures are estimate as data for off-grid energy solutions in developing countries, such as burning of charcoal or kerosene lamps, is often not available and can be carbon-intensive.

**FIGURE 4** - Carbon dioxide emissions – annual tonnes per person.




Source –US Carbon Dioxide Information Analysis Centre

## 4.4 Manufactured capital

Manufactured capital includes man-made infrastructure and machinery, whether owned by the government or private companies. Privately-owned manufactured capital would usually be incorporated into a financial analysis as an asset and depreciated over time. The use of publicly-owned manufactured capital may not always be allocated fully to the user of that capital.

***Some measures to combat climate change will result in a greater investment in and / or depreciation of publicly-owned manufactured capital than others***

Manufactured capital will be affected by the choice of technologies because each technology will have a different impact on the infrastructure of an economy. The infrastructure may be delivered as a fully-costed part of the new technology. For example, if a new distribution network is required as a result of a new solar facility or a new wind farm, then the costs may be included as part of the project. If a new technology requires a new distribution or delivery system, then the sunk cost of existing infrastructure becomes a wasted resource. This may be a factor preventing innovation. There may also be other externalised impacts on public goods. For example, some technologies will make more use than others of the road network and will contribute more to its depreciation. In most countries, payment for road building and maintenance is not directly correlated with road use, so that technologies that use this publicly-owned manufactured capital more than others may have a hidden cost.

***Climate change itself has an impact on manufactured capital***

And the impact of climate change on manufactured capital is another important factor. As outlined in section 2.1 above, both privately-owned and publicly owned infrastructure and machinery will be affected by climate change and this needs to be taken into account in all investment in new technologies.

## 4.5 Financial capital

Financial capital has no intrinsic value but it is used to measure the value of different stocks of capital and it can be allocated to different capitals to release their productive power. As outlined above, financial capital does not always fully reflect the full value of the capital it is measuring or enabling.

## 4.6 Optimising outcomes across the five capitals

In principle, the greatest global public good will be achieved by the technology that maximises the value of the five capitals, taken together. In practice, there are many reasons why “five capitals maximisation” will tend not to take place.

***Inadequate identification of issues***
It is extremely difficult to clearly identify the impact of different technologies on social, human, natural and manufactured capital and, although much work has been done there is still an enormous amount of rigorous research required.

The issues vary not only by broad technology type but also within each technology type depending on the specific materials used, the production methods, the location of production, the nature of distribution and so on. The summary pages on the different technologies below begin to highlight some of the key areas of impact, but within many of the technology types there is a range of different approaches and each has to be considered on its merits.

***Difficulties in measuring the impacts***
Even after the impacts have been identified, it is extremely difficult to measure them in a way that enables comparison between different technologies. The London Accord is playing an important role in addressing this shortfall by setting a framework for assessing the costs incurred by various technologies in reducing carbon emissions.

But the carbon emissions in the life cycle of the technologies are seldom fully measured and costed. And in terms of the impacts on other elements of natural capital (such as water quality and availability, air quality and biodiversity), on individual livelihoods (human capital) or on communities (social capital), we have no ready tools for analysis.

Work being done on carbon labelling in various sectors will bring a more systematic framework to bear on measurement of the carbon footprint of various products, and the learning can be used for new technologies. But, as we have seen from the example of goods being air-freighted from developing countries to the UK, where reduced purchasing of these products has a direct impact on human capital in the producer countries, this focus on one capital at the expense of all others could in some cases create unintended net reductions in global capital.

***Challenges in incorporating the value of impacts into decisions***
Even if they could be identified and measured, the long-term value of the capitals tends not to be incorporated into investment decisions because appropriate incentives are not in place.

***Maximising personal capital at the expense of global capital***

No incentives exist for people to maximise global capital. Governments need to play a role in enabling systems which they believe will maximise national capital (based on their particular free-market or interventionist philosophy) and possibly even global capital. Regulations, as always, need to play a role in preventing individuals maximising their own personal human and financial capital at the expense of others'. Climate change has highlighted the extent to which our fortunes are linked with those of the other people with whom we share the planet and should focus minds on the necessary common goal of maintaining and enhancing the stock of capitals on which we all depend.

The next section explores the sustainability of different investment options to combat climate change.

# 5 sustainability of measures to combat climate change

## 5.1 Overview

Applying the Five Capitals Framework to an assessment of climate change solutions requires the identification of a complex set of factors. Feedback and multiplier effects can cause one solution to have a diffuse range of impacts across the five capitals. Technology-based solutions will have different implications at different stages of innovation and development.

All technologies have impacts. There is a greater chance that good investment decisions will be made if the impacts are identified, explored and mitigated where possible. This assessment of the sustainability of the various options to combat climate change highlights the principal impacts arising both at the level of an individual installation and as the technology is scaled up.

The summary table below shows some of the impacts on the five capitals.

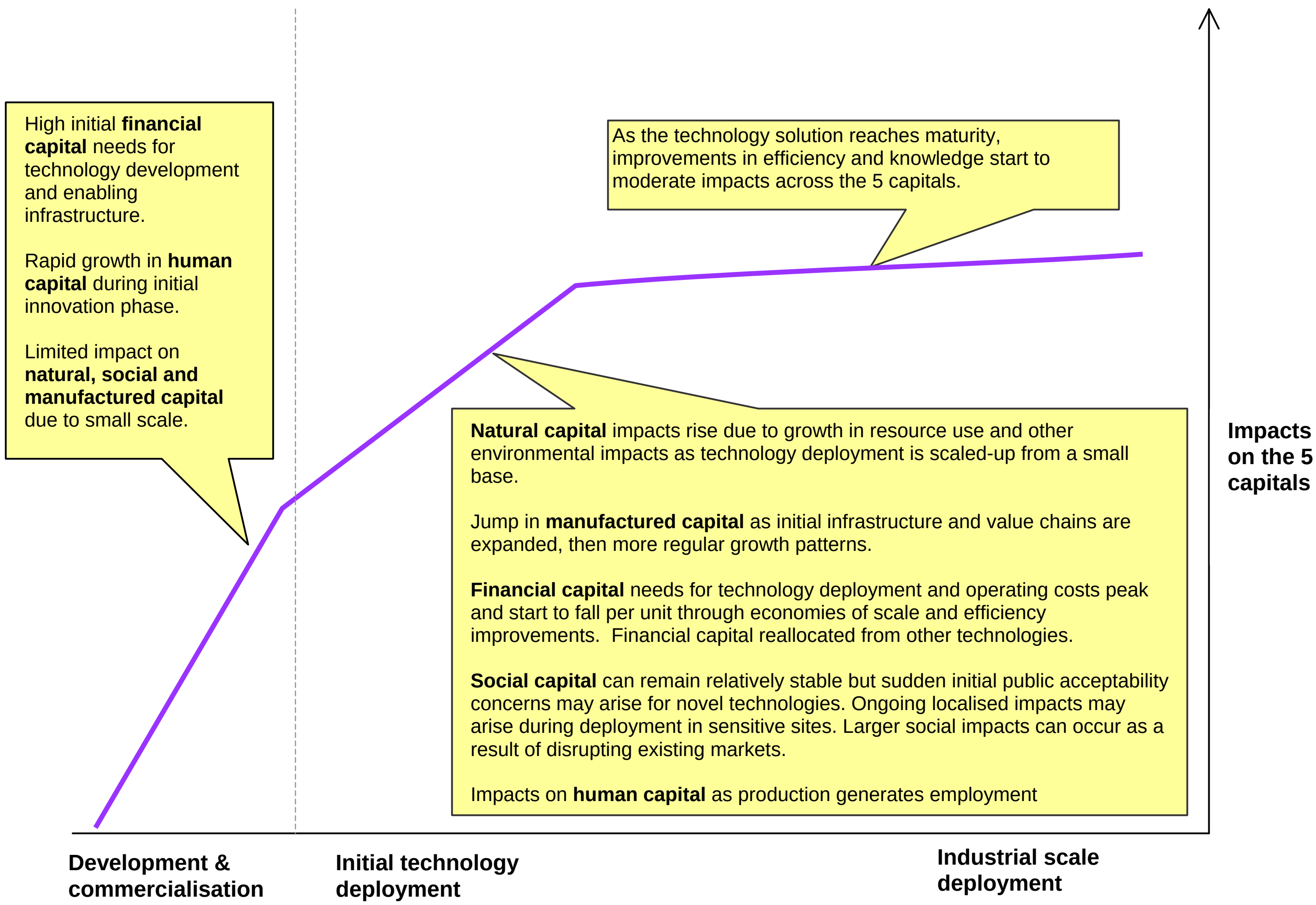
| | Natural | Human | Social | Manufactured | Financial |
|---|---|---|---|---|---|
| Biofuels | - Very high resource use and waste<br>- Negative biodiversity impact | - Limited potential for smallholder farmers | - Inflationary impact on food prices, can undermine food security | - Aligns with existing fuel infrastructure | - Lower upfront investment need but ongoing input costs |
| Solar | - Some toxic materials in 2nd gen PV<br>- Energy intensive manufacturing | - Installation & maintenance skills | - Potential for robust off-grid rural power solutions | - Complex inputs & manufacturing processes | - Very low operating costs but high initial investment |
| Nuclear | - Mining, use & disposal of radioactive materials | - Tested technology with strong skills base<br>- But shortage of / ageing skills | - Security risks for many sites<br>- Catastrophic hazard potential | - Long lead times for construction<br>- Planning & location issues | - Very high economic costs<br>- Unlimited potential decommissioning liability |
| Wind | - Low resource use, some land take<br>- Limited visual, noise & wildlife impacts | - Established skills base | - Some negative impacts on rural communities | - Long grid connections for rural and offshore sites | - Onshore wind competitive installation & operation costs |
| Carbon Capture & Storage | - Untested long-term impacts of seepage<br>- Reduces fuel efficiency | - Scientific & engineering skills for carbon storage not yet available | - Limited disruption to existing lifestyles | - Can be retrofitted to existing plant<br>- Highly complex technology process | - Cost effective low carbon fossil fuel energy with CCS unproven |
| Geothermal | - Potentially renewable resource<br>- Limited local pollution<br>- But possible water impacts | - Limited impacts | - Limited disruption to existing lifestyles | - Relatively simple technology, uses existing drilling & turbine knowledge | - Cost effective in appropriate regions |
| Avoided deforestation | - Maintains ecosystem services | - Enable continued livelihoods<br>- Or lack of livelihood skills for affected individuals | - Could preserve indigenous peoples' way of life<br>- Or could undermine land rights, displace native populations | - Limited impacts | - May need conservation financing vehicles<br>- Some secondary economic impacts |
| Carbon markets | - Impact dependent on carbon price | - Existing origination & trading skills base | - Markets do not generally effectively work for the poor | - Depends on technologies used, but generally minimal impact | - Fragile markets with unclear pricing, validity & consistency |

Key to impacts: very negative; negative; neutral; positive; very positive

It should be noted that many of the technologies have several different forms. The impact of each of the technologies on the environment, individuals and communities will depend on a wide range of factors, including the specific materials used, the production methods, the location of production and the nature of distribution.

It will also, critically, depend on the scale of deployment of the technology. At the development and testing stages, the potential impacts may not be visible but they can have a rapid and unintended effect as the technology is scaled up. Figure 5 shows some of the typical impacts as the technology is scaled up.

**Figure 5** – Typical impacts on the 5 capitals as technologies are scaled up




| ***Natural capital*** | ***Human Capital*** | ***Social Capital*** | ***Manufactured Capital*** | ***Financial Capital*** |
|---|---|---|---|---|
| Resource use, lifecycle wastes, toxicity<br><br>Impact on local environments, biodiversity | Skills and knowledge<br><br>Employment, income, health | Social equity, impact on local communities<br><br>Public acceptability | Infrastructure required for distribution, processing<br><br>Value chains | Operating costs, investment, insurance needs<br><br>Internalised whole-life costs |

Source: Forum for the Future

## 5.2 Biofuels

The sustainability of biofuels has received a lot of attention over recent months. Some describe the technology as a key solution to climate change. Others see it as a destructive industry that will not only not reduce carbon but will also erode other forms of natural capital and deplete human and social capital.

Biomass refers to diverse fuels derived from timber, agriculture and food processing wastes or from fuel crops that are specifically grown or reserved for electricity generation. Biomass can also include sewage sludge and animal manure. Different definitions are used in the literature, but for the purpose of this paper we use “first generation biofuels” to refer to fuels derived from starch or sugar crops (bioethanol) or from vegetable oils (biodiesel), while we use “second generation” to refer to the processes that use more advanced technology to generate electricity from low-value agricultural crops and residues.

There are so many different technologies to be considered under this heading that it is almost meaningless to talk generically about the social and environmental impacts and they need to be separately assessed. Friends of the Earth has prepared a tool which enables a search of the sustainability impacts of different feedstocks[14], and this provides a much more rigorous analysis than can be outlined here. However, some broad themes emerge and are explored below.

***First generation biofuels***
First generation biofuels are made from pure oils from plants such as palm oil, oilseed rape and jatropha, and from bioethanol from plant sugars from sugar-cane, wheat and maize, fermented into ethanol. (Waste vegetable oil that can be cleaned and processed is also a source of biofuels, but this is a limited supply.) Growth of the crops for these biofuels may involve land clearance, with associated depletion of natural and social capital. The palm oil industry, for example, has had a devastating impact on the tropical rainforests in areas rich in biodiversity. The issues of land use, land ownership rights and food security have been explored in depth by WWF[15] and are considered in more detail below.

Land use is a principal concern, depending on alternative uses. While a fossil fuel plant or nuclear site tends to occupy around 1-4 $km^2$ for a 1,000MW plant, the figure for biomass plantations is as high as 4,000-6,000 $km^2$.[16] A solar thermal or PV park would tend to occupy 20-50 $km^2$, while onshore wind requires 50-150 $km^2$ per 1,000 MW (although it may be combined with other land uses).

The water used in irrigation and processing is also a significant issue. It is estimated that every litre of ethanol produced in India requires 3,500 litres of water in irrigation and processing. For this reason and others, climate impacts have to be taken into account in planning – for example, drought resistance and the prevention of soil erosion.

The quality of water is also a vital consideration. As greater pressure is exerted through demand for biofuels, the application of fertilisers and pesticides is likely to increase. There is a risk that the run-off from these products will seriously affect water quality, with implications for both human health and biodiversity. Conversion of land to biofuels from other uses also has an impact on the soil which can result in additional carbon emissions.

Air quality issues associated with biomass technologies vary depending on the type of fuel used, but many of the feedstocks generate high levels of nitrogen oxide and carbon monoxide can be emitted. Particulates may also be produced, but when the technology is produced on a large scale, systems can be put in place to control them. Some commentators have also identified some health hazards with the use of ethanol[17].

Most critically, the production and use of fertilisers and pesticides, and the machinery used to cultivate, harvest and distribute the biofuels generates carbon dioxide. In some cases, this has been calculated to exceed the carbon emissions saved through conversion from fossil fuels.

***Second generation biofuels***

Second generation biofuels are made from cellulose crops such as miscanthus, willow and poplar – and from waste products. This technology results in enzyme breakdown which releases sugars for fermenting, and is known as cellulosic technology. It is anticipated that this may become commercially available after 2010.

To the extent that second generation biofuels use wastes that are continually generated by society, they may be inherently more sustainable and, if they divert waste away from landfill, they can be environmentally positive. If, however, they remove valuable biological material (for example, manure, dead or dying trees or compostable material) that would otherwise have enriched the soil, then they could have a detrimental effect.

The NGO Biofuelwatch has explored the sustainability issues relating to second generation biofuels[18]. It identifies problems in a number of areas.

Firstly, the industry is looking for ways in which plants can be modified in order to simplify and streamline processes to break down cellulose, hemicellulose and lignin. There is a risk that, if these genetically modified plants were developed and planted, this could have a negative impact on existing ecosystems and biodiversity.

Secondly, the efficiency of the technology also depends on microbes and enzymes which will break down the plant matter more effectively, and so researchers are looking for micro-organisms and microbes that might do this, as well as investigating possibility of creating new synthetic organisms to fulfil this function, and there is a risk that these synthetic technologies could have adverse impacts.

Thirdly, the viability of large-scale refineries will depend on a large supply of biomass which could put pressure on existing agricultural land and require an intensity of production that could only be achieved through massive use of pesticides and fertilisers. In turn, this would impact on biodiversity and on carbon emissions.

In the future, biomass technologies may be developed though application of algae and seaweed. These too will have a set of issues to be carefully assessed.

***Biofuels and poverty***

Understanding the relationship between biofuels and poverty is difficult because it is hard to make generalizations across countries: different feedstocks have different effects; existing infrastructure can influence the success of biofuels initiatives; and patterns of land holding are different both between and within countries. However, it is possible to be certain that economies of scale are very important and this favours large producers and large concentration of land, which limits the potential of small autonomous farmer models.

A report by Oxfam[19] has highlighted in particular the problems resulting from the announcement in the EU Renewables Roadmap that biofuels must provide 10% of member states' transport fuels by 2020. Oxfam argues that this has led to a scramble for land and associated quashing of land rights and exploitation, and calls for the EU's sustainability framework to include social standards.

The impact of biofuels on the price and availability of food is also a critical aspect of the analysis. In 2006, US farmers distorted the world market for cereals by growing 14m tonnes, or 20% of the whole maize crop, for ethanol for vehicles. This took millions of hectares of land out of food production and nearly doubled the price of maize. Maize is a staple food in many countries which import from the US, including Japan, Egypt, and Mexico. Plans to allocate substantial hectarage in developing countries to biofuels causes concern because drivers in the industrialised world have greater purchasing power than people needing food in the developing world.

Large-scale biofuels can have a role in providing income for the poor but there is a wide variation in the quality of the jobs created. For example, in the state of Sao Paulo, Brazil, one of the most efficient production areas in the world, one million tonnes of sugar cane creates approx 2,200 direct jobs and 660 indirect jobs, but the quality of jobs is very low and there has been considerable internal migration because the labour demand is seasonal.[20]

New plants and estates can also impact on poverty through reducing biodiversity which can put women especially at a disadvantage because of a loss of natural ingredients used for a range of other products. Individuals in rural communities often provide their livestock with molasses as fodder, but ethanol plants can use molasses to increase efficiency, reducing availability and increasing prices.

From the above analysis, it is clear that the impact of the biofuels industry on natural, social and human capital varies widely. In order to optimise the sustainability of the technology, there should be a clear industry standard, requiring ongoing monitoring and verification. The development of this will not be straightforward, but work has already begun in this area.

***Role in a sustainable energy portfolio***

At present, there is a great deal of speculation and little consensus about what proportion of the energy mix might be provided by biomass. There are two issues: one relating to the net carbon impact of biofuels activities, and the other relating to the extent to which land can be converted to biofuels without a negative effect on biodiversity and poverty. The latter will also have an indirect effect on carbon reduction.

It is clear that some first generation biofuels will not have the desired impact on climate change, whether because they rely on carbon-intensive production processes or because they will lead to the destruction of rainforests and negate the carbon benefits. While some studies[21] have estimated that there is sufficient uncultivated land on which to produce biofuels equivalent to today's oil production, only around 30% of this land is likely to be available on a sustainable basis[22]. Investors should work with NGOs and others to establish criteria and ensure that capital is not allocated to these unsustainable biofuels.

The overall potential for sustainable biofuels depends, of course, on assumptions on yields and on the efficiencies achieved by new technologies. But there is scope for biofuels to provide a substantial part of a new energy portfolio. Some estimates assume that sustainable biofuels could meet as much as 30% of global energy demand by 2050[23] but even if the technologies do not develop to this level, sustainable biofuels are likely to be an important part of the mix.

## 5.3 Solar

Enough solar energy reaches the surface of the earth in one hour to meet all of our current energy needs for an entire year. There are currently broadly two approaches to applying energy from the sun: photovoltaic (PV) technologies and solar-thermal technologies, including Concentrated Solar Power (CSP).

***Photovoltaic technologies***

A photovoltaic cell consists of two or more thin layers of semi-conducting material, most commonly silicon. When the material is exposed to light, this generates electrical charges which can be conducted away by metal contacts. There are several different types of PV cell, using different materials and therefore with varying efficiencies, costs and sustainability impacts.

While solar PV lifecycle emissions are far lower than those created by fossil-based energy sources, they are generally higher than other renewable energy sources. The main raw materials used in the process depend on the specific technology. Some of the most commonly used are glass, ethylene vinyl acetate (EVA), aluminium, quartz, mineral oil and silicon carbide. Resource depletion may become an issue for raw materials used in some technologies. For example, it has been estimated that 30% of the current annual silver production would be required to achieve a 5% contribution to the world electricity supply by base case solar modules[24]. There have been supply shortages of solar grade silicon material because of bottlenecks in the purifying process due to much higher demand and competition from the semiconductor industry.

Some solar technologies involve major hazards in the manufacturing process (see table 2 below). Some of the newer generation of non-silicon PV cells use highly toxic exotic elements such as cadmium.

**Table 2**. Major hazards in PV manufacturing.

| Cell type | Potential hazards |
|---|---|
| x-Si | HF acid burns |
| | $SiH_4$ fires/explosions |
| | Lead solder/ module disposal |
| a-Si | $SiH_4$ fires/explosions |
| CdTe | Cd toxicity, carcinogenicity, module disposal |
| CIS, CGS | $H_2Se$ toxicity, module disposal |
| GaAs | $AsH_3$ toxicity, As carcinogenicity, $H_2$ flammability, module disposal |

Source: Overview of potential hazards by Fthenakis.[25]

During operation, PV cells are environmentally benign, emitting no pollutants or greenhouse gases. However, solar power may have visual impacts. For example, some people may consider a large system operating on a rooftop or on land to be obstructive or unsightly. However, these effects can be mitigated through employing design or siting options that make the cells less conspicuous or more attractive. Thin-film modules can be especially helpful in this regard.

In terms of decommissioning, studies have indicated that the aluminium module frame is the only component which is easily recyclable.

***Solar thermal technologies***

There are many different solar thermal technologies and some are more commercially advanced than others. The technologies include relatively simple small-scale water-heating solutions that can be rolled out off-grid to individual homes, and large-scale technologies which use concentrated solar power (CSP) to drive a conventional steam turbine or to drive chemical processes such as the production of hydrogen.

CSP schemes tend to be developed in desert areas. While the environmental impacts may appear on the surface to be limited, the risks to complex ecosystems in these areas will require careful assessment and management. However, this technology looks attractive from a sustainability perspective.

***Opportunities for off-grid solutions***

The benefits of solar energy can include the decentralisation of energy and power.
In developing countries, there are many benefits from the off-grid solution presented by small-scale solar power. For example, clinics can use PV solar home systems (SHS) to provide lighting during check-ups or operations. The availability of PV power for phone chargers has made it possible for people in rural areas to use mobile phones. This increases business opportunities, and also allows people to maintain contact with family members[26.]

The advantages of decentralised production are not only felt in places where on-grid solutions are not available. Even in industrialised countries, there can be a significant increase in efficiency though decentralisation of the power supply, and the more local “ownership” of energy production can be more effective at changing consumer behaviour.

The opportunity for solar power to enhance social and human capital, in particular where it can be delivered off-grid to rural areas, is therefore considerable. The costs are currently high relative to other renewable technologies such as wind but prices will start to fall dramatically as manufacturers scale up production.

***Role in a sustainable new energy portfolio***

The constraints arising from development of this technology to scale, from a sustainability perspective, relate primarily to the land required. The Princeton wedges model, for example, assumes that solar PV will need to grow by 700 times to cover 10 million hectares to deliver a 1 gigaton reduction in carbon dioxide. New technologies, particularly those used on buildings, could help to reduce that constraint.

The shortage of some raw materials such as silicon could also affect the sustainability of particular technologies. And the life cycle impacts of new technologies need to be assessed as they come on-stream.

But broadly solar power offers a highly attractive sustainable energy source.

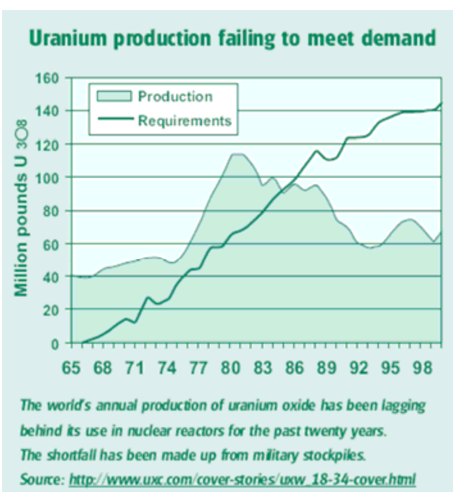
## 5.4 Nuclear

Probably the most controversial of all of the investment options to combat climate change, nuclear power generation is the subject of much worldwide debate. Some environmental experts - James Lovelock, for example - take the view that the threat of climate change is so great that, despite the evident disadvantages of nuclear plants, they present a lesser evil than what is seen as the only currently viable alternative of increasing use of fossil fuels. Others maintain that the sustainability downsides cannot be outweighed.

Nuclear power makes low-carbon electricity available for base-load generation, and this clearly has advantages. However, from a sustainability perspective, there are a number of concerns.

Firstly, the process is by its nature not sustainable as it relies on a depleting resource and uranium production is unlikely to be able to meet increased demand. The timing of any crunch in terms of stock depletion will evidently depend on the number of nuclear plants in place but if all countries decided that nuclear power had to be a part of the solution to their lower-carbon energy needs, then shortages could occur before the end of the useful life of plants built in the next few years. (If all of the world's power were generated through nuclear energy, then one estimate is that the supply of high-grade uranium would last 6 years[27].) Figure 5 shows the supply and demand of uranium from 1965 to 1998.

**FIGURE 5** – Uranium production and demand




Source: Why Nuclear Power cannot be a major energy source – David Fleming, April 2006

Secondly, nuclear power is not "zero-carbon". Uranium enrichment requires large amounts of electricity that usually come from fossil fuel sources, and the contribution that nuclear power will make to low-carbon electricity will reduce as high-grade uranium is used up and lower grades are brought into production. Also, the construction, operation and dismantling of a nuclear plant, safely sequestering the spent fuel and repairing the environmental damage can be very energy-intensive. The nuclear industry has undertaken life cycle assessments which show that the carbon dioxide emissions of a nuclear plant spread over its life equate to renewable forms of generation such as wind, hydropower and solar. However, many commentators contest these findings[28], especially when the energy costs of disposing of material (which has not yet been undertaken) are brought into the equation.

Thirdly, uranium mining and processing can result in toxic contamination of local land and water resources, and can be a safety risk to mine workers and nearby populations. Abandoned mines can continue to pose radioactive risks for as long as 250,000 years after closure[29]. High-grade uranium is limited and switching to lower grade uranium will require even more processing and an even higher impact.

Fourthly, there is currently no solution to the problem of the disposal of highly hazardous radioactive waste.

Fifthly, nuclear plants that rely on water for their cooling systems require two and a half times as much water as fossil fuel plants. Many nuclear plants were sited near coasts so that sea water could be used for cooling, and this creates additional concerns around vulnerability to potential sea level rises or extreme weather events resulting from climate change.

Sixthly, no facility is ever 100% safe. The risk of an accident can be minimised but never removed, and the potential for damage if something goes wrong remains huge. Seventhly, the materials used in nuclear power stations can be diverted to nuclear weapons. If nuclear power is the right answer for energy generation in some countries, then why would it not be for all, and this would have consequences for nuclear proliferation.

Eighthly, a focus on nuclear may divert resources from the innovation of alternatives in terms of efficiency and renewables. Nuclear power is not innovation-friendly and has a long lead time.

And finally the economic costs of nuclear plants are very high and the costs of the technology are unlikely to fall. A recent paper by Henderson Global Investors[30], for example, prepared as a response to the UK Government’s consultation highlighted this factor as the principal reason for arguing against the development of new nuclear plants.

***Role in a sustainable new energy portfolio***
While nuclear power will be a part of the energy mix, at least until current facilities come to the end of their useful life, there are many arguments against nuclear power playing a central role in the fight against climate change. Alternative technologies have more scope to deliver sustainable, scaleable and timely energy supplies, and capital would be more effectively allocated to these.

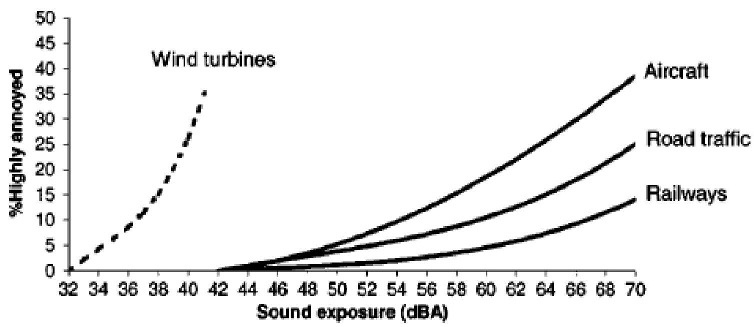
## 5.5 Wind

Wind power is the world’s fastest-growing electricity generation technology. It is also the lowest-cost renewable energy technology currently available. At the best wind sites, wind plants are nearly competitive with the conventional natural gas-fire combined-cycle plants, even without taking hidden pollution costs into account.

The impacts of wind power generation on sustainability arising from the electricity generation process itself are visual, noise and wildlife impacts. The visual impacts arise from the fact that they are very large constructions, often in remote and unspoiled areas, and on high ground to maximise wind power so very noticeable. Many people object to this intrusion on the landscape and this can result in significant social costs though they are little quantified and will vary with culture and location[31].

As far as noise is concerned, people seem to be much more susceptible to turbine noise than other sources of low frequency noise, as shown in Figure 6 below.

**Figure 6** - Graph of annoyance with the loudness of different noise sources[32]




Source: Pederson & Waye 2004

This means that the noise pollution from turbines might be more of an impact than is at first apparent. This seems to be mostly due to the swishing of the blades and the low background noise of their rural locations making them more intrusive. However, surveys indicate that the fear factor of the expected impact tends to be much greater than the actual impact.

There are also concerns about the impact of wind farms on fauna (especially birds).[33] The Royal Society for the Protection of Birds (RSPB) has carried out many assessments and is of the view that appropriately positioned wind farms do not pose a significant hazard for birds. However, they recognise the damage done to birds in US and Spanish sites where the farms are poorly-sited. And the RSPB objected to 76 UK wind farm proposals (on- and offshore) between 2000 and 2004 on the grounds of adverse impacts on bird-life. The RSPB acknowledge that the negative impacts of fossil fuel-based technologies are potentially much greater, because climate change will have such a devastating effect, but is very clear about the need for careful assessment of each individual proposal.

Aside from the electricity generation process, the construction and decommissioning of a wind farm has social and environmental impact. A full life cycle analysis carried out for the Vestas wind turbines[34] provided an assessment of the most important factors in determining the whole-life sustainability of a wind farm. These were –

- the wind conditions on-site, which are a fundamental determinant of cost per unit generated
- the size of the plant
- the distance from the grid, which determines the length of the cables required to transmit the electricity – as wind farms are often in remote places, this can be very long
- the life-time of the plant

- how the raw materials are disposed of at the end of the wind farm's life –the blades are normally incinerated but the glass content can be used for insulation and the steel can be recycled.

But wind energy has very small-scale life cycle impacts in comparison with other energy sources.

***Role in a sustainable new energy portfolio***

Wind power will be a critical part of a sustainable energy mix. It is currently the lowest-cost renewable technology. It has a low carbon footprint over its life cycle. While there are some concerns over impact on landscape and on wildlife, appropriate siting will often address these issues. Modern wind farms do not tend to generate significant noise. Research carried out in 2005[35] found that locations with sustainable winds worldwide could in theory produce 72 trillion watts, which would meet global demand many times over. On a more practical level, Friends of the Earth has estimated that producing 10% of the UK's current electricity from wind would require about 1% of the UK's total land area, with turbines only occupying 0.02%[36]. In time, offshore wind could deliver a substantial proportion of global energy needs.

## 5.6 Carbon capture and storage

This technology differs from the others in that it is an end-of-pipe solution that simply captures the carbon emissions rather than reducing them.

The primary argument against carbon capture and storage (CCS) technology is that it will prolong the fossil fuel industry and not mitigate the other pollution that it causes. There is a danger that the life of existing fossil fuel power stations will simply be extended by equipping them with CCS technology, without a proper analysis of the feasibility of replacing the power station with energy efficiency technology and of the scope for renewable energy generation. And, when new power generation facilities are being built, the perverse subsidies available to fossil fuel power generation might make fossil fuel generation with CCS look relatively favourable.

Secondly, an IPCC Report[37] shows that the extra fuel needed to run CCS reduces generation efficiency by 15-30% depending on the type of plant. In addition, CCS raises the total cost of production by 20-85%, mainly due to the need for extra fuel. Furthermore, due to the additional fuel, CCS also increases emissions of sulphur oxides and nitrogen oxides or requires extra systems to control them.

Thirdly, there is currently no understanding of the impacts of long term carbon dioxide retention, nor of the potential impacts of seepage on marine and land environments. In many areas of the world, carbon dioxide is released from the ground naturally but seepage into environments not adapted to it could have negative impacts. When dissolved in water, carbon dioxide forms a weak acid which could affect sea water or water in aquifers, and this could have an impact on drinking water.[38]

Greenpeace has explored the leakage issues associated with different disposal sites[39] and has argued that there should be no direct disposal of carbon dioxide to the ocean, sea floor, lakes and other open reservoir structures because of the dangers of acidification which would have an impact on ecosystems. WWF shares this view[40]. Other storage locations have their own problems – for example, salt domes are at risk of water breakthroughs, deep coal seams could fracture and there are known and unknown well bores in depleted oil and gas fields which would have to be sealed. In addition, there are safety concerns associated with large leakages.

In all feasible scenarios, fossil-fuel technologies will continue to contribute a substantial proportion of the energy mix well into the future. This is partly because of inertia and because the infrastructure is already in place. But oil and gas supplies will become more and more vulnerable to political pressure, resulting in increasing use of coal which is readily available in the countries with the highest energy demand, including China, India, the US, Russia and Europe.

It is critical therefore that the CCS technology evolves to address the environmental concerns outlined above.

The World Resource Institute (WRI) has set up a project to get businesses, government, NGOs and other interested parties in the US together to build consensus on project guidelines for CCS. 75 stakeholder organisations are involved with the project and there are two working groups, one on siting and monitoring and another on liability and accounting.[41]

***Role in a sustainable new energy portfolio***

Given the rapid rate of growth of energy consumption, CCS will play an important role in reducing the impact of carbon emissions, at least in the short to medium term. However, the technologies are unproven and the underlying processes are unsustainable so this is not an alternative to development of more sustainable solutions and it should not receive any preferential support.

## 5.7 Geothermal

Heat from the earth – or geothermal energy – can be accessed by drilling water or steam wells. Three types of power plants are operating today: dry steam plants, which directly use geothermal steam to drive turbines; flash steam plants, which draw out deep high-pressure hot water and use the resulting steam to drive turbines; and binary-cycle plants, which use moderately hot geothermal water to heat a secondary fluid which creates vapour to drive the turbines.

Geothermal liquids contain small amounts of dissolved gases such as carbon dioxide, although these amounts are approximately 50 times less than the level in fossil fuels. Geothermal production can result in discharges of small amounts of other gases (such as hydrogen sulphide, ammonia and methane) and dissolved chemicals (arsenic, boron, mercury and sodium chloride) but these are site-specific and usually small.

There are issues around the drilling and discharge of water from the ground and the potentially damaging effect this has on ecosystems. Increasingly, systems involve the reintroduction of geothermal liquids into the ground after the energy-generation qualities of the heat have been extracted, and this reduces the disruptive effect.

Enhanced geothermal systems involve injecting water and improving the permeability of the rock, so that a wider range of locations can be considered. The impacts on water supply and on natural systems need to be carefully assessed at each project site.

***Role in a sustainable new energy portfolio***
Geothermal energy is assumed to be available only in very limited locations. In fact, there may be scope for sourcing geothermal energy in a wider range of places in the future and work is going on in many parts of the world to uncover its potential. In the US, geothermal energy may be capable of delivering up to 10% of energy needs.

## 5.8 Avoided deforestation

It is estimated[42] that nearly 20% of annual carbon emissions come from deforestation. There is enormous scope for action on avoiding this deforestation, but the social, political and cultural landscape is very complex.

Markets do not currently value forests properly because they do not (and have no systems to) take account of the vital ecosystems services they provide, not only in carbon sequestration but also in water catchment, flood control, biodiversity, amenity value and other benefits. As a result, there is an economic incentive to convert forests to a more “productive” use – for example, crops for food or for biofuels. In many countries, illegal logging is the norm and the rewards from deforestation do not in any case flow in a straightforward way to the land-owners (often government) or to the traditional communities that use the land.

Buying up forests in order to prevent them being depleted may seem superficially attractive but fails to recognise the importance of land rights, the vested interests of many powerful people in those environments and the livelihoods of those who depend on the forests.

Avoided deforestation is attractive as a tool against climate change because it does not require any new technologies to be brought on-stream. However, partly for that reason, it is very difficult to incorporate avoided deforestation into the carbon markets. How can someone pay for the carbon reduction associated with not doing something, especially when it is illegal to do it? There is also the problem of “permanence” – forests are effective as carbon sinks, but only for as long as they are alive and the rate at which they absorb carbon will vary according to climate and the health of the plant. If payments are being made to reduce carbon as a quid pro quo for producing it somewhere else, then rigour is required in the analysis of the actual carbon reduction achieved.

Avoiding deforestation has positive impacts for the estimated 350 million of the world’s poorest people who rely on forests almost entirely for their subsistence and survival needs. A further 1 billion people depend on remnant woodlands and agro-forestry systems for their essential fuelwood, food and fodder needs. Any initiative to improve the rate of avoided deforestation has to be designed in full consultation with individuals and communities in developing countries to prevent charges of “carbon colonialism”, and to achieve buy-in for the critical action required.

## 5.9 Carbon Markets

Carbon markets obviously seek to address the fundamental market failure, through internalising the externality of carbon emissions. The evidence on whether the carbon markets have yet helped to fundamentally shift company behaviour is, however, mixed.

Aside from the impacts on carbon, the carbon markets have the potential to affect other natural capital, and social and human capital. In particular, the activities of carbon offset companies and projects qualifying under the Clean Development Mechanism (CDM) of the Kyoto Protocol should deliver social benefits through increased investment in developing countries. However, the direct contribution made by regulated carbon markets to international development is restricted for a number of reasons -

***CDM projects have tended to be large, not oriented towards poorer people***, and overwhelmingly focused on China and India rather than Africa. The implementing agencies are supposed to review the extent to which projects deliver development benefits in line with national strategies but this is seldom done in any meaningful way. To date, almost 60% of the emissions reductions achieved under CDM projects have been achieved by just 11 projects involving the destruction of potent greenhouse gases (HFCs) used for refrigerants in China, with minimal impact on investment or development. Large-scale hydro projects have qualified for carbon credits under CDM, although many observers do not consider these schemes to be environmentally sustainable and they are undoubtedly not pro-poor.

***Developing countries' forest assets are not properly valued***. While some plantation forests can qualify as CDM projects, there is currently no mechanism for including avoided deforestation within the regulated carbon markets.

***Poor people usually have very low carbon emissions.*** The scope therefore for projects that combine carbon offsets with pro-poor impact are limited. The pro-poor projects developed to date include biogas, micro hydro, cooking stove projects, and replacement of wood or charcoal with other fuel sources. These do deliver carbon reductions but are often much more expensive to create per carbon unit than larger-scale projects. At the current price of carbon, or even at the higher price allocated by carbon offset providers such as Climate Care[43] and the Carbon Neutral Company[44], many projects of this type are not economic. However, they do deliver additional benefits for health, income generation and biodiversity.

## 5.10 Energy Efficiency

The most sustainable option to combat climate change is reduction in energy demand. Given that people are likely to resist a reduction in their energy utility, the most attractive solution is clearly to use less energy for a given task. This has cost advantages as well as reducing emissions and the overall energy footprint. There is considerable scope for energy efficiency in buildings and vehicles. Some require new technologies but much relies on behaviour change. Sometimes this is possible through a realignment of incentives, for example by ensuring that tenants gain financially from more efficient use of energy.

## 5.11 Sustainability Criteria

From the analysis above it is possible to outline the criteria which will determine the sustainability of various options to combat climate change. All energy sources will have a social and environmental impacts, but a review of sustainable and unsustainable criteria will provide insight into the likely balance of costs and benefits.

**Table 3**: Sustainability criteria

| | |
|---|---|
| **SUSTAINABLE CRITERIA** | **Changes behaviour to reduce consumption** |
| | **Increases energy efficiency – industry, buildings, transport** |
| | **Enables flexible off-grid solutions** |
| | **Makes effective use of existing infrastructure** |
| | **Implements "closed-loop" systems for manufacture** |
| | **Low-cost solution** |
| | **Protects water and biodiversity** |
| | **Increases energy security** |
| **UNSUSTAINABLE CRITERIA** | **Changes land use, especially where livelihoods are negatively impacted** |
| | **Generates unrest in local communities** |
| | **Damages biodiversity** |
| | **Diverts scarce water from other uses** |
| | **Generates waste that cannot be effectively reused and is not biodegradeable** |
| | **Depletes resources in the process of manufacture or operation** |
| | **Generates emissions of greenhouse gases which contribute to climate change** |

Source: Forum for the Future

# 6 conclusions and recommendations

The following key themes emerge:

- Investor interest in options to combat climate change is growing, as evidenced by the level of investment in specific cleantech funds and by the launch of many climate change-themed funds[3]. The London Accord will play an important part in developing this interest.
- There is still much too little investment to meet the challenge of climate change.
- Models suggest that existing technologies can be deployed to deliver the solutions we require.
- The impacts of different options on wider sustainability need more sophisticated analysis. This is not only because this will ensure that they are commercially viable in the longer-term. It is also because the impacts on natural capital, people and communities will affect whether a particular option will in fact deliver the carbon emissions reductions expected.

And the principal recommendations arising are:

- In order to manage risks and develop opportunities, investors should
    - recognise the economic and financial imperative to combat climate change;
    - develop tools to assess how climate change might impact the economy and investment portfolios, highlighting the need to invest in clean technologies;
    - require rigorous research of sustainability impacts for all investment options to combat climate change, and develop criteria for investment that include both social and environmental safeguards;
    - undertake further research into the challenges posed as new technologies scale up, and how to address them;
    - actively consider the construction of a diversified portfolio of investment options to combat climate change, possibly by means of emerging index products.
- In order to incentivise increased investment in measures and technologies to combat climate change, Governments should
    - improve regulation to require higher technical standards for energy efficiency, particularly for buildings and vehicles;
    - consider tax incentives for funds designed to invest in options to combat climate change, provided they incorporate sustainability criteria;
    - further explore how to make more constructive links between the interconnected agendas on carbon and international development, particularly on forestry;
    - ensure that clean technologies are viewed as part of an innovation and competitiveness agenda, enhancing skills and opportunities.

[3] Investor awareness of the materiality of this issue across their portfolios and in all sectors is also growing (as seen, for example, in commitment to the Carbon Disclosure Project) but this paper focuses particularly on clean technologies.

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# 7 appendix

## Tables of sustainability of climate change solutions

The risk values are qualitative and are relative to the impacts that current substitutes are having. (i.e. if current technologies were swapped instantly for this technology what would be the difference?). They take into account the magnitude and likelihood of potential impacts and are the net impact upon that impact type (i.e. if there are potential pros and cons it's the average of them).

-2: highly negative impact;
-1 significant negative impact;
0 - no overall impact;
1 - significant benefits;
2 - highly beneficial.

The first three tables show the impacts of operation of the various technologies on various aspects of sustainability, while the fourth shows the impacts throughout the life-cycle.

| | POTENTIALLY GLOBAL ISSUES / IMPACTS | | |
|---|---|---|---|
| **LOW-C OPTIONS** | **Land Use Change** | **Genetic Pollution** | **Developing Countries** |
| **1st gen Biofuels** | -2: indirect land-use change due to increased demand for land | -1: development of new varieties with higher yields / tolerance | -1: land use change and food security impacts hit hardest on DCs offset by economic development and energy security |
| **2nd gen Biofuels** | -1: limited impacts due to development of marginal land offset by economic development and energy security | -1: development of new varieties with higher yields / tolerance and improved enzymes | 0: limited impacts due to development of marginal land offset by economic development and energy security |
| **Carbon Capture and Storage** | 0 | 0 | 0 |
| **Large-Scale PV Solar** | -1: 20–50 km² per GW | 0 | 2: domestic energy supply, tropical and equatorial regions have potential to export |
| **Large-scale Thermal-Elect Solar** | -1: 20–50 km² per GW | 0 | 2: domestic energy supply, tropical and equatorial regions have potential to export |
| **Nuclear** | 0: same as coal | -1: from radioactive release | 0: lower availability and higher cost than coal |
| **Large-scale onshore Wind** | -1 significant land required if onshore (50-150 $km^2$ per GW) but could be marginal land. | 0 | 2: domestic energy supply decreased cost and increased security, scaleable in rural settings, 'can be microgridded' But even onshore wind is more expensive than fossil at the moment |
| **Large-scale offshore wind** | 0 - Offshore does not result in land use change | 0 | 0 |
| **Forest/Peatland Conservation** | 1 – Prevents land use change in the actual forests being conserved. Knock-on impacts will depend on how conservation activities are handled, whether they present livelihood opportunities to local people etc | 0 | 2: could be a sustainable source of income with financial vehicles for conservation |
| **Forest Restoration** | -1: could cause indirect land use change if it displaces agricultural land | 0 – Assuming that forests are not created with genetically modified material | 0 – with a wide variation around that mean. Impacts on developing countries depend on approach taken, extent which local communities are consulted and involved on an ongoing basis |

| REGIONAL / NATIONAL ISSUES / IMPACTS | | | | |
|---|---|---|---|---|
| **LOW-C OPTIONS** | **Food Security** | **Water** | **Air** | **Energy Security** |
| **1st gen Biofuels** | -2: direct and indirect land use change cause food price increases, exporting countries will benefit | -2: irrigation; leached agrichemicals; increased runoff | 0: mixed conclusions on emissions from bioethanol/diesel | 2: diversification of fuel-producing regions |
| **2nd gen Biofuels** | -1: see 1st gen but less land use change so effect smaller | -1: see 1st gen but feedstocks need fewer inputs | 0: mixed conclusions on emissions from bioethanol/diesel | 2: diversification of fuel-producing regions |
| **Carbon Capture and Storage** | 0: same land demand as current | -1: lower generation efficiency means water intensity increase | -1: lower generation efficiency means increase in emission to air | -1: lower generation efficiency means more feedstock hence more sensitive to supply issues |
| **Large-Scale PV Solar** | -1: minor land use demand increase | 0: same demand or less | 2: low emissions to air | 2: domestication and diversification of energy generation |
| **Large-scale Thermal-Elect Solar** | -1 Less impact as can be located in marginal non food areas | -1: higher water use in water scarce areas | 2: low emissions to air | 2: domestication and diversification of energy generation |
| **Nuclear** | 0 | -1: 2x fossil plant water use | 1: some low level isotope emissions but overall cleaner than fossil | 1: less dependence on import of fossil fuels but reliance on access to other raw materials eg uranium |
| **Large-scale on-shore wind** | 0: little land use displacement offset by supporting farming with a diversified income | 1: less water demand than current, little hydrological impacts | 2: very few emissions in life-cycle | 2: domestication and diversification of energy generation |
| **Large scale offshore wind** | 0 | 0 | 0 | 2: domestication and diversification of energy generation |
| **Forest/Peatland Conservation/ Restoration** | -1: could cause land use demand and raise food prices | 2: maintain/restore hydrological function | 2: absorb pollutants | 0: n/a |

| IMMEDIATE ENVIRONMENT/LOCAL ISSUES / IMPACTS | | | | |
|---|---|---|---|---|
| **LOW-C OPTIONS** | **Landscape Impacts** | **Noise** | **Ecosystem Health** | **Employment / community** |
| **1st gen Biofuels** | -2: direct land-use changes cause loss of fertile, high biodiversity areas to monocultures, but could be offset by multi-cropping | -1 Agricultural machinery | -2: habitat destruction, agrochemical and water demand impact soil, land and rivers | Could support local agricultural activities |
| **2nd gen Biofuels** | -1: as 1st gen but development of marginal areas and higher yields means less land use change | 0 | -1: as 1st gen but less due to higher yields | Could generate employment in waste handling |
| **Carbon Capture and Storage** | -1: lower efficiency will require larger/more power plants | 0 | 0 Impact on ecosystem health will depend on proper functioning of storage systems – the carbon is still being generated and could still impact ecosystems in the event of release | Limited |
| **Large-Scale PV Solar** | -1: land use change, solar fields<br>Some people may consider a large system operating on a rooftop or on land to be obstructive or unsightly | 0 | -1Toxicity of advanced materials, mining impacts | Ongoing operational activities limited |
| **Nuclear** | 0: similar to fossil plants | 0 | -2:potential for radioactive releases to air, soil and water | Some local employment for skilled operators |
| **Large-scale on-shore Wind** | -1: visual impact | -1: noise is particularly annoying even at low levels due to frequency. | 0: some possible impacts on birds but little known | Ongoing operational activities limited |
| **Large-scale offshore wind** | Usually no landscape impacts if sufficiently far off-shore | | 0: some possible impacts on birds but little known | Ongoing operational activities limited |
| **Forest/Peatland Conservation** | 2: may maintain natural habitat | 0: n/a | 2: maintains natural/semi-natural habitat | Could generate substantial local employment and amenity value for communities |
| **Forest/Peatland Restoration** | 2: may restore natural/semi-natural habitat, although depends on intensity of plantation | 0: n/a | 2: restores natural/semi-natural habitat | Could generate substantial local employment and amenity value for communities |

| | LIFE CYCLE IMPACTS | | | | |
|---|---|---|---|---|---|
| **LOW-C OPTIONS** | **Raw materials** | **Production process** | **Distribution** | **Disposal of process waste** | **Decommissioning** |
| **1st gen Biofuels** | Depends on pathway.<br>GM crops | Fertiliser with high fossil fuel content<br>Agricultural machinery uses fossil fuels<br>Some bioenergy crops need intense tilling and harvesting, breaking up the soil<br>Use of water for irrigation may cause a problem in arid or semi-arid regions | Transportation will often be by vehicles using fossil fuels | | Depends on infrastructure |
| **2nd gen Biofuels** | From waste | GM enzymes can be used to break down waste | As above | | Depends on infrastructure |
| **Carbon Capture and Storage** | Infrastructure requires cement, steel etc | No additional production entailed | Distribution impact if $CO_2$ transported to storage | N/a | The carbon dioxide would have to be stored indefinitely |
| **Large-Scale PV Solar** | Main raw materials are glass, ethylene vinyl acetate (EVA), aluminium, quartz, mineral oil and silicon carbide<br>Polysilicon material for PV has been in short supply | • Much of the production is in developing countries which may generate high-value employment<br>• PV production can be energy-intensive<br>• Some thin-film PV cells contain toxic substances, such as cadmium or arsenic, which could be released in the event of a fire or accident.<br>• Some hazardous substances in the production process | Varies | None | Aluminium is the only component that can b easily recycled |
| **Large-scale Thermal-Elect Solar** | | Some systems use molten sodium nitrate salt (eg Solar Tres in Spain) which has some safety and environmental concerns | | | |
| **Nuclear** | Cement – high $CO_2$ in manufacture<br>Uranium mining – environmental impact locally | Dangerous process requiring very careful monitoring.<br>Threat of sabotage | Electricity distributed through grid | Disposal of radioactive waste – not yet resolved | This stage of the nuclear process has not yet been resolved. |
| **Large-scale Wind** | High $CO_2$ in manufacture of cement for foundations.<br>Wind turbine blades – fibre-glass and polyester<br>Landscape impact | Noise pollution – noise can be annoying even at low levels due to frequency.<br>Possible impact on birds | Electricity distributed through grid | None | Decommissioning required, including removal of foundations |
| **Forest Restoration** | Depends on source of planting material | Could result in alternative land use with negative impact on local people; or could generate new sources of livelihood | None | None | None |

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