

THE DARWIN INITIATIVE

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**SCIENCE FOR SUSTAINABILITY
AND SUSTAINABILITY FOR SCIENCE
Dr Ashok Khosla**

[Presentation with slides]

I shall take you through a roller-coaster story just now, which is kind of a personal journey that I would like to share with you but how professionals, practitioners like us, have to treat the trust that society has placed in us to do certain things. It is really about how we now have to think not just about doing things that we as professionals have been taught to do, but to do them right and to do them in the sense that a doctor, who takes the Hippocratic Oath, does so with a much wider goal in mind.

In a few minutes, I would like to present what I believe is the global problematic. The reason for that is not because you don't know it but it is because, in order to present you with some solutions, I need to tell you what I believe the problems are. I shall then try to identify some of the causes, the impacts of those problems, and then I shall try to present to you three different ways in which we might go into the future: three ways which have very different outcomes and implications. Finally, I would like to see what we as scientists have to think about in order to return the trust that society has placed in us.

There are some 40 percent or 2.5 billion people on this planet who live probably as well as anybody in history has ever been able to live. They live fulfilled, comfortable and rewarding lives in circumstances that even emperors of old could not have imagined. Then there are some 60 percent of people – I don't want to get into the exact number which may be 55 or 65 percent – close to 3.5 or 4 billion people on this planet who have not been able to get the comforts and rewards of living in a civilisation that has benefited so much from science.

We have something of the order of 1.5 billion people who do not have clean drinking water, which is by WHO standards. I just want to remind you that the WHO standard says that you have clean drinking water if there is a source of water within 1.6 kilometres or 1 mile of your dwelling. So you can imagine getting up in the middle of the night when you feel thirsty and you want a glass of water, you will have to walk some 20 minutes each way to bring yourself a drink and you are counted as having clean drinking water. There are around two billion people who do not have access to cooking fuel without having to put in a huge amount of effort to get it. This lady who is cooking in her kitchen is smoking the equivalent of around four packs of cigarettes a day from the pollution from that kind of fuel.

Some 2.5 billion people do not have access to any commercial energy, let alone electricity. Something of the order of two billion people still on this planet do not have toilets. They are eking out all kinds of livelihoods and their children – around 30 million babies are born every year – are stunted from malnutrition. Something like 1.5 billion people on this planet cannot read or write, and we have to live together and this is the one, and only one, planet that we have.

One of the problems that I want to put on the table that needs a solution rather urgently is this incredible disparate income distribution. Some 60 percent of the people of this planet earn between them some 5-6 percent of the income, and that gap, according to most statistics, is growing.

We have destroyed the countryside in each of our countries and we have to recognise that we are all joined together. This is not something that can be isolated and shoved away but whether physically through the atmosphere, the ocean currents, life support systems of the planet, or through our institutions, we are in it together. We are on this lifeboat and, if one side of it is leaking, all of us will have problems.

Here is a picture of Mount Kilimanjaro in 1970, and this is a picture 30 years later taken from the same place: the plot of the ice cover of Kilimanjaro speaks for itself. Over the last 30-40 years, we have seen changes in the Greenland icecap, in glaciers in the Himalayas and the Alps. We have seen floods and droughts increase and forest fires, and vector-borne diseases are expected to grow by huge amounts as the climate starts to change.

The annual temperature trends, as shown on this diagram which comes from the IPCC and the United Nations, show according to the size of the red dots how much hotter the Earth has become. This is the same kind of map for precipitation: almost everywhere precipitation has gone up except in some of the deserts where it has gone even further down. This is the temperature for plotted for thousands of years and expected over the next few decades – a veritable hockey stick, just going up. Carbon-dioxide, nitrous-oxide, you name it, it is all hockey sticks. Over the last 20-30 years, everything is exploding – hockey sticks. Atmospheric nitrogen, surface temperatures, climate disasters, urbanised land, loss of biodiversity – everything is happening in the last 30, 40 or 50 years. Water use, McDonald's restaurants, paper – everywhere you go there is a hockey stick and you know hockey sticks can hurt. This is a world that has just run amok and all we have done is destroy the countryside.

No matter which country you visit, you see indiscriminate logging and a complete massacre of nature. Everybody knows rosy periwinkle from Madagascar, crucial medicine

for childhood leukaemia: how long will it last? Unless the Darwin Initiative is successful, we shall be in trouble.

Then there is the whole question of energy peaking and this is from petro-consultants who are in the business, who claim that we have pretty well already peaked on oil, though not on gas yet for another few decades.

You probably remember this chart from the *Limits to Growth* which was published 40 years ago, which shows pollution, population, resources etc. A third edition which came out a couple of years ago – *Limits to Growth Plus: the 30-Year Update* - showed that we are pretty well exactly on track. The mathematics that they used in 1968 were very crude but the amazing thing is that they were right: we are pretty well on track on every single curve.

Our times are characterised by rapid change: in technology, in the economy, in our geo-political relationships. Also our people around the world are expecting much more too. Ultimately, the people in this room are all conversant with the need to bring together economics with societal and environmental issues without all of which we are unlikely to be able to find the right answers. However, science is progressing very rapidly. This is an amazing graph from a book that recently came out, and I recommend that you all look at it, which is called *The Singularity is Near*. The book is written by Ray Kurzweil and I do not know how many of you know him but when he was an undergraduate at MIT at the age of 19, he decided 35 to 40 years ago that he would figure out a way to read books to blind people. In the process of developing that machine, he invented the scanning machine, the fax machine, the synthesiser – all of you who go to discos would not have anything without Ray Kurzweil – voice recognition, voice synthesis and all of that. This man knows a great deal about technology and was President Clinton's advisor on science and technology.

His book demonstrates by a simple process of extrapolation that technology is moving so rapidly that by the year 2013, we shall have machines that compete with the human brain in terms of function capability. By the year 2025, the combination of human beings and machines will flip civilisation into some totally different way of working. These are not a century away, we are talking of the next decade when things will change rapidly.

The question that a person like me, who works in villages with very poor people, asks is, if science can do all of this, why are there so many of us who were left out? This is called Moore's Law which is very well known, and it says that every 1.2 years the computing power doubles, and it has been doing that since 1990. The next curve which I did not copy shows that it has been doing it in fact since 1930 from the time of mechanical relays, then vacuum tubes, transistors, integrated circuits and all the way up. This is a law that seems to be pretty well inexorably in the cards. All I am saying is that, if this is what science is capable of

doing, why do we have so many problems? Are scientists addressing the wrong ones, or are they just oblivious to the suffering and the mass deprivation that exists in this world?

We have set up huge mechanisms such as the United Nations, the World Bank and virtually everybody on this planet is now able to see television. This woman does not have a toilet but she has a television, so she knows what is going on in the world, and her aspirations are being fixed by what she sees every day.

Let us just look at what we are doing to ourselves. This is a chart that comes from a wonderful book called *Factor Four* which I shall say more about in a minute. It is written by a German called Ernst Ulrich von Weizsäcker, who until recently was a parliamentarian and Chairman of their Parliament's Environment Committee, a very well known person who has done a lot of work on climate, energy and so on. In his book, he describes the kinds of agriculture that we have today and he says that traditional agriculture, way down on the right-hand side, used to use one calorie of inanimate energy for the input to produce 50 calories of food energy. However, we now go to supermarkets which are at the other end and are producing animal and vegetable calories which require 500 calories of energy input to get one calorie of food energy out. That is nonsense. We talk about climate change and so on but we are doing this every day: every time we go to the supermarket to buy all that stuff, that is what we are encouraging. Every time you buy something out of season that has been imported all the way from South Africa, that is what you are doing.

I shall come back to this diagram but I just want you to remember that the horizontal axis is about energy efficiency. On this side, if you like, it is highly efficient which is why you have this big green arrow, and on the left-hand side is hugely consumptive, inefficient energy.

These are not the only goals that we have. We have other goals in society such as justice, equity, creating jobs and employment for everyone, meeting the basic needs of every single citizen on the planet, and maintaining the health of the environment. These are all just as critical as any of the issues that I have just discussed. I want you to keep in mind that these are the issues that I shall try to address now in my different scenarios and how we might get there.

The one thing that is clear is that you cannot have a sustainable world if you have the kind of disparities that you have today. That Champagne glass approach to income distribution and wealth creation is just not going to work. It is not only because it is politically and socially unfeasible, because sooner or later people will ask, "Why are we excluded?" and, of course, that will happen, but it is ecologically not possible. There is a very good reason for it. The rich tend to over-utilise what we call non-renewable resources – limits to

growth, remember all those curves? Overshoot and collapse – overshoot and collapse – that is the problem with the rich. They tend to over-utilise the fossil fuels, iron ore and all the resources that nature has put in place for humankind and they do it within literally a couple of centuries.

However, if you are very poor – and it is not fashionable to talk about the poor attacking the environment – out of the exigencies of survival you have to tax the resource base. What do you tax? You tax what are called renewable resources but, of course, you make them non-renewable very quickly but that is what you do. Thus when you have great disparity, it is ecologically not sustainable: it is politically not sustainable, it is socially not sustainable but it is ecologically suicidal, because at both ends you are destroying the resource base and the life support system.

We got into all of this business and we looked at these things. Over the last 20 years I have been involved in many different initiatives, some of which will come through in my little story. This is an initiative that looked at how much of our natural resources come into use and how much go into discard and mess up the rest of the world, and we shall look at that in a minute. We called it the “ecological rucksacks”. This is a basic approach that mainly originated in Germany in the Wuppertal Institute but a number of us came together and formed something called “The Factor of 10 Club”. We studied everything from sand and gravel, stone, steel, gold and all the other substances, and looked at what are the rucksacks, what are the side-effects of utilising these resources.

This slide always disappears but it comes down here and it says that, while the industrial countries will have to reduce massively their use of materials, the developing countries will have to go up a little and then come down so that they end up in 40 or 50 years more or less the same. Why? If you do the calculation right now, the amount of material that we are moving from one place to another is getting close to geological movements. The amount of physical material that we are moving is not very different any longer from what nature has been doing, which means, as all of you scientists know, that you are having a massively disruptive impact on the environment.

This is another way to look at the same thing and is a different school of thought, using the metaphor of an ecological “footprint”, and all of you know about that now as it is quite well known. The green part is the biocapacity of an area, and the red part is the amount that people are using, and I shall come back to this as it is part of my analysis of how you go through different things. You can see that various countries have different kinds of footprints, and these footprints change over time.

The story that I want to share with you is that mono-disciplinary research and studies are not enough. As David said in his introduction, the moment you get into real issues, you find that you have to start looking at the whole picture. In the case of nature, this is even more important. I spent a good part of my misspent youth studying systems, and what I learned from my studies was that systems are very important, and I shall give you dramatic examples of how important in a minute, because they are more than the sum of their parts, they are very complex, very hard to predict and very often they do the opposite of what you think they will do. There is a formal jargon term in systems science called “counterintuitive”: they often behave in exactly the opposite way to what you think.

It is very important for us to understand efficiency, because the people in the other part of your universities – economists – have pulled the wool over our eyes by defining efficiency in ways which happen to suit them but do not happen to suit nature. From that you have to look at what happens when you design systems, and many of them have feedback loops and delays built into them, which are such that it is often too late for your controlling action to have impact. That leads into what is called overshoot and collapse, which is a very strong element of many of the systems that we deal with. Industrial ecology is about how a good system in nature teaches us that there is no such thing as waste: the waste of something becomes the raw material of another. Thus if there is no such thing as waste in nature, why should there be waste in our manmade systems?

There are several levels of efficiency in cybernetics, in system science. One is the simple engineering efficiency: output over input, that is the normal one with which most engineers are familiar. In a sense, it is a rated efficiency – what is. The higher level than that is something I shall call potential efficiency. There was a wonderful British cyberneticist called Stafford Beer who is no longer alive, who developed these theories of efficiency which I am using here, as a way of explaining how we can get more and more out of nature with less and less. Potential efficiency is what should be – if you do things right, what you should have. Then he had a higher level still than that which he called latency or latent efficiency: what could be if you changed some of the basic parameters, not deep structural change but if you change some of the assumptions, then you could get even higher levels of efficiency. Finally, there is systemic efficiency: what would be if you change the fundamental assumptions altogether. For example, if your overall objectives are changed, you can get at a higher level.

The most amazing thing I believe that system science gives us is that idea of counterintuitive. I shall plot here against time the quality of life based on the premise that the powerful and rich in this society that will be described here have the power to allocate resources. What do they do? They allocate resources to do the things that are of interest to

them. Let me take this as a concrete example. City people love to say that their city does not get enough money and there is a need for more. If you spend too much money in a city as compared with the hinterland, the city becomes more and more attractive and more and more people from the hinterland find it necessary to come into the city. This is called the rebound effect and, as you do that, your basic quality of life deteriorates again. So here are the poor of the hinterland, and you put more and more money into the city, their quality of life goes down, that is obvious. The interesting point is that, even from the point of view of the rich, it goes down. So whether we are looking at the North versus the South, the industrialised countries versus the poor countries, whether we look at the city versus the hinterland or the countryside, if your investments get out of balance, everybody suffers. In fact, that is what is beginning to happen around the world. The rich have tended to put their investments into things which are now beginning to have overshoot and collapse.

Now what are the fundamental choices? I suppose if I were living in England, I would say I have three choices: business as usual so just continue to do things as we do them; do a little fine-tuning here and there to try to improve things wherever we can; or, if we are going to think of the long term and the future of our children on this planet, we may want to look at deeper systemic change.

In the South in a country like mine, the question is very similar but, though I left it out here, the red one would be to copycat, so just copy the way things are in the US, Japan or in England if I were an African country or India; the yellow one would be should I piggy-back and take the good things they are doing and adapt them to my circumstances; the green one would be leap-frog, so I just jump over the whole thing, forget about how they live and design my own future. Therefore, whether I am in the North and I am in the red – BAU (business as usual) – or whether I copycat, there are certain implications, and I shall try to play through these three implications for you, because they are the ones we are going to meet in the next 10 years.

The first one with the red background – it is all colour-coded so you can see where we are – is the pursuit of so-called global competitiveness, which automatically ensures that we use copycat strategies. Economists will tell you that, if you do not compete, you do not use the same machines, you do not use the same economic tools, you do not use the same technologies, you get left behind. These ones lead to the kinds of things that have been happening. We have all talked about the future of the planet being saved because there is trickle-down, we use very heavily resource-intensive solutions, we are talking about large-scale projects with short time horizons: these are the characteristics of “business as usual”. It is all subsumed under this term “Washington consensus”, which says that whether you are rich or poor, you need to have certain kinds of financial disciplines and approaches which

will help to solve the economic competitiveness problem. That is what business as usual looks like, whether it is in the North or in the South: it is all about massive rape of the Earth, it is about efficiency in production. It is easy to be efficient if you are getting someone else to pay the cost. They call it “externalities” because they are not in your calculation.

According to the World Bank, half a million people in China and half a million people in India today die premature deaths because of air pollution from that “business as usual” scenario. Efficiency – get lots more out of your land, just spray it with all the chemicals you can find. Efficiency – run-off, pesticides, fertilisers, chemicals. This woman, as you can see from the number plate, is from Tamil Nadu, she is from near Chennai, Madras. She did exactly what she was told to do by the government extension officers and the companies who were selling her agrichemicals, pesticides, fertilisers and within six years her land was finished: there was no way she could grow anything on it – business as usual. She has nothing to fall back on. Business as usual: big dams, let’s go out there and master the universe. You need water, set up a water treatment plant – business as usual. In New York City, they gave them an estimate \$6.5 billion, \$300 million every year for drinking water. Efficiency – fine.

You remember that I told you about those rucksacks. This is a gold ring, how much do you think it weighs? Say, 20 grams. In fact, it weighs 20 tons because that rucksack is big. It is amazing that with these bottles, 10 times as much water goes into making the bottles than is in the bottles. A finished cotton shirt takes 40,000 litres per kilogram of cotton. Thus in “business as usual”, we are really working at that end of our agricultural efficiency chart, and we have a Champagne glass that is really stretched out. I am not sure what you put into it but it is *really* big at the top end, and your ecological footprint grosses the place out. In fact, today according to WWF and the Ecological Footprint Institute, we are running at about 1.2 for the planet: we are using 20 percent more than the planet sustainably produces around the world. I believe that to very few people in this room, it would be difficult to disagree that this is a dead-end approach. It leads to more exclusion, more alienation, more violence and overshoot and collapse, and in the process you lose all the cultural, social and economic capital that you have built up. What does it look like? It is overshoot and collapse, that is where we are heading.

Let us try the second one – piggy-back. Piggy-back is about improvements in our approach, it is about changes, the kind of changes that Ernst Ulrich von Weizsäcker was proposing in his book *Factor Four*. The iPod is an example of a good factor four technology. It used to be that we had hi-fi systems that were that big, they became smaller and smaller, there was the Walkman and now you have thousands of hours of music in a little machine that big. That is the kind of thing that we can do to save ourselves some grief or at least to

buy some time. These can be incentivised, you can develop market-based incentives to promote them, and they involve a certain amount of change. It is difficult to see the globalised economy being able to continue to maintain the kind of transportation of goods and services across the planet if transport is no longer subsidised. It is because it is so hugely subsidised that some of the prices are so far out of whack.

Now we are getting into a higher level. Remember that I talked about efficiency; now I am talking about potential efficiency. I am talking about better housekeeping, better and cleaner technologies, energy-saving, many ways in which we can improve things, and this is the kind of thing that the environmental movement largely is looking at today. *Factor Four* was a bestseller, it was a report to the Club of Rome and it showed a number of examples of the nonsense economics and the nonsense approaches that we make. I don't know how many of you have read the book but this diagram is about strawberry yoghurt, and it so happens that the strawberry yoghurt carton is a favourite breakfast food in many parts of Switzerland and Germany.

This lady researcher from the Wuppertal Institute followed a carton of strawberry yoghurt from its origin to its destination until it landed up on a breakfast table in Stuttgart. It had travelled 5,280 kilometres. Our economics are such nonsense that they shipped it all the way from western Germany in Cologne or somewhere, all the way to Budapest to print the label, because ink is cheaper in Budapest. Nature is giving you a subsidy because everything that you provide in this virtually free transport, free goods and services that you get from nature are not being counted. Then she did the whole thing again by producing local strawberries, yoghurt and so on, and she could do it for one fifth or sixth of the cost. We have set up systems that are preordained to drive the ecosystem into the ground.

In the case of piggy-back, I would say that it is largely in the centre of this chart: it is from one calorie in/one calorie out to perhaps 15 calories in/one calorie out. However, now we have all kinds of other things like cars, hypercars, we are beginning to get technologists, architects, construction people, electricians, compact fluorescent. Now you have these incredible LEDs which may well be beyond factor of four already. However, by and large, technology through various means can buy us a little time. Factor of four is important because it is difficult for economies suddenly to jump from zero to one, it has to go through steps. There are many different things now such as clothes, houses, refrigerators, cars and so on, and while there is nothing bad about piggy-back options, they will not get us there. It is important for the time being to try to use them to the extent we can, and they will help us to moderate the disparities of income because they will make it possible for poorer people to be able to get the same services like cooling, transport or whatever and, to some extent, to stand on their own two feet, to be innovative and be able to deliver new technologies in their

own domains. Now we are beginning to see the possibility of not having to overshoot and collapse any more: perhaps we can put the collapse off by a few decades.

The third route is the difficult one but not impossible. Many of you must know that there is one little country in this world which has tried to do this, and that is the country of Bhutan just north of my own country in India, where they have defined a way, so that rather than GNP being the objective of their country, it is gross national happiness. They are now in the process of defining it in such a way that it includes long-term survival of life support systems that they need.

Leap-frog does imply rethinking what is it that life is about. How do we define our own social objectives? How do we adopt not factor four but perhaps factor 10 solutions? How do we develop an innovation capacity, because many of these solutions will not come from somewhere else – other people are not interested in finding them – and how do we adapt our institutions? They will certainly imply changed relationships between both the individual and the community, because the community becomes more important now, and between people and nature.

Our Factor of 10 Club is looking at latency, pushing the frontier all the way up as far as it can to look at clean technologies, material saving technologies, creating awareness, teaching people that they have to think of the future in everything that they do. I showed you that picture of the water treatment plant and this happened in 1997, when the City Fathers of New York City said we need more water or we will die of thirst. So they put out tenders and they had many bids and \$6.5 billion was one of the lower ones. Then a bunch of NGOs came along and said, no, no, that is a water treatment plant but so is this and it does not cost so much, it is up in the Catskill, we clean up the watershed over there and, instead of having to pay \$6.5 billion and \$300 million every year, you can get this for one tenth of the cost with no operating expenses. It turned out that even that one tenth of the cost - \$700 million – they recovered over three or four years because of the added tourism, so even that did not cost them anything. Now we are talking about a different approach, a different technology, a different way of doing things. The water is better, there is more of it and a few engineers are out of business – not a bad price to pay, huh? *[laughter]* A few economists, a few engineers here and there and everybody has their water.

My own work for the last 20 years or so has been to try to develop a model of sustainable development that relies on creating vast numbers of livelihoods, jobs, and my own organisation called Development Alternatives has its home in New Delhi. It works all over India and some other places. In the back, you will see the Indian National University – in India everything is named either after Nehru or Ghandi, so this one is Nehru University. It

is made entirely out of concrete, steel, huge amounts of cement, stone and it is a monolithic monument to whatever. This one is the headquarters of my own organisation – Development Alternatives – and we are rebuilding it now because, at the time we built, we had 30 members of staff and now we have 600 so we have to expand it. However, then and now it has no cement, no steel, no wood and no bricks, it is made out of mud, and it has no air-conditioning. It is an example of doing things differently: nature can do it, engineers can do it. If you want to save the planet, we have to rethink what we do and how we do it.

My organisation spends a good part of its life creating livelihoods and basic needs products: things like better cook stoves for those women I showed you the pictures of, machines to make compressed earth bricks which do not need any firing, which is this machine here. This was used to build this National Exhibition Centre, called Indira Gandhi National Centre for the Arts, next to the Meridian Hotel right in the middle of Delhi. It was built for a cost that was less than the cost of a tent, which was what they were planning to put this exhibition in. They were planning to put a tent up, I said give me the same amount of money and I will make you a building, and it took 122 days to put it up right out of the ground. It is a different way of doing things, it is still there 18 years later and there is no way they will let it go because it has become a famous landmark.

These people are making roofing tiles which we developed with very intensive research. It took us seven years to develop it but it is the cheapest roof in India today, as cheap as thatch, but it lasts 40 years as long. You see that people with middle class homes are even using them.

Handlooms, recycled things – everything that I wear comes out of our machines. Recycled paper, everything that you can do to create jobs. Small dams – these are remarkable. This particular dam has a connection with the UK. There was a gentleman called Sir Tony Greener, who was the Chairman and Managing Director of United Distilleries Guinness, and then he became the head of Diageo when they were floated. He wanted to open a distillery in India so he needed some PR, so he came to my office and said, “I would like to put some money into a water project”, which he called the Water for Life project. We said there is no water there, there is no point putting pumps in because the water has gone, but if you give us some money for dams, we will revive the water table and people will love you for it. So he gave us enough money to make five of these and the next year he was so proud of them, he came back for a picture to be taken at the dam sites, and he got his distillery too. These are little dams that cost £7,000 but the return on investment is several thousand percent per year. These people were living in a desert with no crops or perhaps just one, and now they have three crops. There are fish, wild life has come back, there is

water in the wells, the whole economy has been transformed not to mention the swimming and recreation. Little investment – huge impact.

This weed is an alien species which came in from Costa Rica about 150 years ago. It is called ipomia and in Hindi it is called Shameless, because the more you cut it the more it grows. In fact, my friends in Pakistan tell me they call it Politician! It is a weed that can be transformed into nothing: you cannot cook with it because it smells too bad, you cannot feed it to the animals as they won't touch it, you cannot make baskets or furniture out of it, it cannot be used, it is just wasted. We convert it into electricity through this gasifier, which is a very sophisticated device. It was developed in collaboration with the top technical university in India and we sell it at a price that is cheaper than the grid and make money.

This is a brick factory which saves 55 percent energy, and the World Bank has given us a \$3 million project to put 287 of these up from carbon emission reduction money. Organic farming, internet facilities in every village so that the farmers, housewives and everyone can make use of these opportunities, and now we are talking about promoting an agriculture that begins to make sense, where you are getting more calories out than you are putting in. That is when you can hope to have some kind of sustainability.

Now I believe we need to move to the next factor, a factor of 50 or perhaps 100, and that involves systemic change. Development Alternatives is what I have been describing to you. I also happen to be trustee of an organisation called ZERI – Zero Emission Research and Initiatives. I work very closely with them and Development Alternatives in India is ZERI for South Asia. However, the project that I am going to tell you about is not in India, it is in Colombia, and it is a very important project because Darwin Initiative will have to pay attention to this one.

It is a project that we call driven by the five kingdoms of nature, which you all know, and you have probably heard the term “biomimicry” – learning from nature or making nature. Nature not only does your work for you, which it often does for free but you learn from nature on how to design technologies. The story that I shall tell you right now is both ways: it learns from nature but it also uses nature to a maximum extent, and it does so in a variety of ways.

This is in Vienna in Europe: how can you clean buildings without detergents for example? How can you learn from nature about colouring things without pigments? This is a welwichia, which is a plant in the Namibian desert and is one of the oldest living things. that particular plant is about 2,800 years old: can you imagine what scientists could learn about ageing from that? It also helps the local bushman to get water because it condenses water in the early morning like the desert clover. This welwichia is a phenomenal plant which is the saviour of the people and the animals who live there.

Here is a zebra and did anyone think why it is black and white? It is its private air-conditioning system. The zebra is a very interesting construct because, if you look under those black strips, you will find much more fat than you will under the white strips, and those little moths have found out that there is a circulation of air which is keeping it cool. Those termites taught us how to make the links, and this is a very famous building called East Gate in Harare which has no air-conditioner but has the highest rents in the city: it uses the principles of the zebra and the termite for cooling the building down.

Let me show you the Colombian experiment. This is way out in the Vichada, right next to the Orinoco, just across the river from Venezuela. There is nothing there. There are some trees that can grow along the rivers, the soil is pH5-6 so nothing can grow there and the few people who live there – one person every four square kilometres – has gastroenteric diseases. There is no industry: no agriculture, no forestry, nothing, just drug runners and a few people who are escaping from civilisation. So we set out to take the savannah and make it into a tropical rain forest to be able to deliver large quantities of water, biodiesel, wood, logs and sustainable communities.

We started in 1994 and had we taken on any single one of those projects – clean drinking water – it would have cost billions. We would have had to borrow the money from banks, set up factories, set up road networks and so on, but because we did it as a system, we could get all of those for virtually no investment at all. The investment into this project was to the tune of around \$1,000 per hectare.

How did we do it? We found many good scientists, people like yourselves, to tell us how to start the process. They said we should find a species of tree which is water-friendly but not dominant, so that once it gets going other species will come through. They chose the Caribbean pine and told us that the micro-riser that goes with it is this thing called *pisolithus tinctorius*, and we developed a whole nursery. We drenched the place, we bought those tractors for \$1,000 a piece second-hand, we developed a whole system of planting, and we were able to plant something of the order of one tree every two seconds and we covered the whole area.

This land is so bad that the price of the land is \$1 per hectare, so we bought 8,000 hectares and planted the whole place up. Within about three and a half years, you are now starting to build up the humus and a variety of species start to come in: the birds, the bees, the beetles, the bats – everything beginning with a “b” starts arriving! They all came along bringing many seeds and very soon we started getting a diverse forest. Now we are into the sixth or seventh year and we start getting some very interesting things out of this forest: colofonia resin which, if you know what that is, is used for violin bow strings and coffee table

art paper, very expensive, \$200-300 per kilo, so we started tapping that. We also started getting araza which is a fruit that has the highest vitamin C content and all kinds of stuff. We even had to set up a factory to process it because we might as well add value right there and make some money. That shows colofonia packed, ready for shipment through the Orinoco all the way up to Miami, and you get several hundred dollars for each box.

What happens in the forest, as you all know, is that the water regime changes. There is sometimes more precipitation and certainly more of it goes into the ground and recharges the aquifer. We found that this happened here. The drinking water production went up hugely and the place started looking like this: we found some 10 percent increase in water availability. You see these children, they think they are playing but in fact they are pumping water! We just put everybody to work wherever we could, and this lady is measuring the quality of the water. In fact, the quality of the water was so good that we sent it to Dr Masajiro Imoto in Tokyo, the guy who looks at water, and he says that this is among the best, cleanest crystals of water he has ever seen and he was comparing it with Antarctica and the Himalayas.

You see this bottle – it looks strange. We were worried about people littering the now tropical rain forest that we have generated, so we wanted to make sure that people would not want to throw their bottles away. We made them into Lego bottles and patented them, and they stick to each other, so who will want to throw away a Lego bottle as their kids want to play with them? In fact, if you collect enough of them, you can build a house. These are used to collect 13 cubic metres, 13 tons of clean drinking water per hectare per day, which is a lot of water. This water can sell at roughly the same price as Evian if you can get it out of there.

This is araza that I told you about. We package this, it is a favourite drink in Bogotá and that bottle sells for \$2 in Bogotá – everybody buys it up as soon as it arrives. Then we planted 110 steering palm trees in each hectare, because by now we are cutting down trees to keep the productivity high. The stearic palm leads to biodiesel immediately, no processing, no transesterification, no refining – just strain it through a piece of cloth and you have biodiesel. I am talking about large quantities of biodiesel which go straight into your car.

That is the story. This was 12-15 years ago when my colleagues started work here. They built a hospital because everybody was sick and it had 25 beds. Now it has only one bed because we give away the water free, even to the drug-runners, everybody is entitled to free water, whoever comes near us gets free water. This hospital now has one emergency bed for snake bites and things like that but nobody is sick any more, and how few hospital

beds you have is also a measure of development. It has now been converted into the water testing lab.

My colleagues are nuts so they give away a free guitar or a free set of paints and brushes to everybody – anybody in that area is entitled to either a free guitar or free paints. We are talking about Colombia, which is one of the most violent countries in the world, and in 11 years we have had not a single case of violence in this area, to the extent that the army has given us all their land: they said if you can do that, we would be happy to have you on our bases and everywhere else.

Much more interesting than that is the fact that the President of Colombia, President Uribe, has personally given us a lease deed for 3.6 million hectares in the Vichada: that is the size of Holland, Belgium and Luxembourg put together. He has handed over this land and now we have to go out and somehow convert it. It is an interesting challenge because every hectare, which requires about \$1,000 of investment, produces about one third of a job, produces 13 cubic metres of water, large quantities of fruit and food, 18 tons of carbon fixed per year, which is selling in Europe for around €15-20 per tonne, so you can see that that alone is worth around €300 and so on. We have all of this for only \$1,000 per hectare because nature did everything. We are talking about a different science of different engineering. It is not Mickey Mouse stuff, we are talking about a lot of money.

JP Morgan, the investment bank, has put in \$225 million for the first 225,000 hectares with the option of going the whole way to the \$6.3 billion if we meet certain milestones in the next to years. The Government of Colombia has given the land, we are providing the expertise and the total package is coming out to \$325 million – that is sizeable. Who is doing all the work? Those little creatures such as bacteria, algae and fungi are doing all the work and it is creating jobs.

What I came here to share with you is that we need to start thinking differently. We need to start thinking about how we can make bankable projects – there is nothing wrong with that – that use nature's processes to produce the goods and services that all of us need and to do so in a way that is sufficiently holistic and systemic whereby everyone can benefit. I did not want to overload you with too much information but the analysis of this is that in the next 10 years, with the kind of money we are getting now from various investment bankers, people who want their money back, we are talking about bringing in 8 or 10 million people into this area as settlements and townships and providing every one of them with a full-paid job. Our approach to the jobs is that every job we create has to be 50 percent more than the minimum wage.

I have taken a little extra time and I shall not tell the rest of the story as I have run over time but, if we are going to do this, our research has to look at ecosystem services in a much more pragmatic way. We need to understand what they are really worth and you will remember that about seven years ago *Nature* published an article that they were worth around \$33 trillion and \$33 trillion in comparison with the economic GDP of the world is only \$20 trillion, that means that nature is already doing something like twice as much as human beings are doing for us. Then the only question that remains is where is it all going, who is getting all this value? Is it only serving to make the rich richer, or will we have a world where everyone will get something out of it? At the moment, much of the costs are being paid for by very poor people and much of the benefits are indeed going to the very rich, like that Catskill Mountain example.

However, we can do it differently. I have tried to identify what are the research needs and it seems to me that the kinds of research that we are doing are wonderful and need to be continued, but they need to be supplemented by the kind of questions that need these answers. It is not just the aggregate, it is also the distributional aspects that are very important. Ultimately, it is about technologies and institutions and how we bring those together. Thank you. [*applause*]