Issues in a World of Environmental and Societal Vulnerability

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ABSTRACT: Human activity has brought increased risks for irreversible damage to the global environment. An increasing world population and expectations for a better standard of living carries an unsolvable dilemma. An uncontrolled development can make the life supporting platform of the earth increasingly vulnerable. The vulnerability is also mediated through societal instability where escalating local conflicts may end in major environmental damage. Better models are needed for understanding interaction between society and the environment. A global management of resources is one way to decrease the vulnerability of present systems. The paper evaluates issues of environmental and societal vulnerability and means to avoid irreversible environmental damage. A prudent approach towards broad issues of environmental protection and societal stability should make it possible to decrease risks of environmental catastrophes.

1. INTRODUCTION

The modern industrialised society has been able to produce an increasing wealth for its members. This wealth has been achieved by a large scale utilisation of technology. Human activity can through various technological systems influence the global environment, but technology has not changed the fact that mankind depends on an undisturbed ecological base. A continued wealth can build only on a sustainable use of available resources where major disturbances of ecological systems are avoided.

Examples of environmental vulnerability on a global scale are the influence of CFCs on the ozone layer of the earth and the possibility of global climate change from energy related emissions of CO_2 and other greenhouse gases. Indications of environmental damage should initiate countermeasures, but various obstacles can make their implementation difficult.

Technology has through new processes and the scope of their utilisation increased the vulnerability of the life supporting platform of the earth. At the same time an increasing world population with escalating demands on quality of life mount increasing pressures on the resource base. A new situation has developed where threats for global environmental damage are amplified by the vulnerability of a technological society.

One possibility to decrease risks of global environmental damage is to create systems for a management of global resources. It should be possible to identify and control threats both to the environment and to the society. Issues of concern in building such systems are discussed below.

2. ENVIRONMENTAL VULNERABILITY

Nature is a system which is in a dynamic equilibrium. Various forces balance each other and changes in their relative strength move the equilibrium. Many relationships are non-linear and chaos can thus make evolution difficult to predict. An increasing number of new substances emitted to the environment may create new problems.

2.1 Global impacts

The impact of human activities on the local environment has been demonstrated in many places in the world. In some places local pollution has even reached levels where immediate consequences on human health are observed. Local problems can often be solved by closing pollution sources and cleaning up the environment. Sometimes it may be necessary to evacuate people from a contaminated area. Global impacts are more difficult to react on.

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The influence of CFCs on the ozone layer of the earth was the first example of a global environmental impact. International agreements to ban CFCs have been seen as a victory for environmental diplomacy. The depletion of ozone layer is still expected to increase for many years to come, due to accumulation of earlier emissions.

The risks of global climate change connected to energy related emissions of CO_2 and other greenhouse gases are well known. There are still controversies around strength and timing of the mechanisms, but some of the projected scenarios are extremely costly. If for instance the Gulf-stream providing warm water to the northern Atlantic would stop, it would be disastrous for Europe.

2.2 Sensitivity and irreversibility

A dynamic equilibrium can be sensitive to small changes in boundary conditions. Dynamic equilibria are often stable in the sense that balancing forces increase with an increasing offset from the equilibrium, but the region of stability can be small. If a system is brought to a point where forces cannot restore the balance it goes through an irreversible path of change. Sensitivity is also increased by positive feedback in the systems.

Dynamic equilibria formed by interacting species in a biota often demonstrate such behaviour. Even small changes in environmental conditions can cause an irreversible change. This may happen as a consequence of release and accumulation of toxic or other substances which changes the environmental balance in the biota.

Accidents are another example of sensitivity and irreversibility. A minor technical failure or human error may through a complex sequence of events cause a major release of toxic substances. If such releases take place in environmentally sensitive areas even a small release may have irreversible consequences. Accidents usually have only local consequences, but the Chernobyl disaster demonstrated that dangerous substances can spread over very large geographical areas.

2.3 Uncertainty

There are many uncertainties, both deterministic and probabilistic, which are connected to mechanisms of environmental impact. Deterministic uncertainties can be qualitative, i.e. there is a disagreement on the existence of a certain mechanism. It can also be quantitative i.e. the disagreement is connected not to the existence, but to the strength of the mechanism. Probabilistic uncertainties are involved when mechanisms of chance influence initiating events and contributing conditions.

One specific uncertainty is connected to new substances exposed to the environment. Each year thousands of new substances are synthesised, which have not before been found on earth. Each of them may show unexpected influences. When a large number of substances interact some of them may have synergistic effects.

Probabilistic uncertainties influence all technical systems through occasional variations in the quality of materials and components. If these sum up in an unexpected way with minor deficiencies in design of the system a major accident may be the result.

2.4 Interactions with the society

Environment and society interact in many ways. An industrialised society puts a heavier load on resources than a less developed society, but technological processes are more efficient. Research and development have the potential to decrease environmental impacts, but rely on a surplus of resources.

Societal policies may be implemented to discourage emissions to the environment, but economic realities may offset their effect. Environmental protection cannot for instance get much support in a society where its members are starving.

Even if convincing evidence is found that a certain technology is condemnable, it may be difficult to terminate its use. Invested capital and costs of introducing a substitute can be very large. Defenders can also ridicule evidence and delay agreements on a phase out. There may even be a continuation of emissions through criminal activities, as the case of CFCs demonstrates.

In a time of economic growth new technologies are taken into use rapidly and on a global scale. The concern given to scientific warnings of possible environmental impacts may not then get much attention in the beginning. When warnings are recognised irreversible damages may already have occurred.

3. SOCIETAL VULNERABILITY

Societal tension between groups of people can be the cause of wars if mutual retaliation escalates beyond control. Local conflicts can have a global impact in many ways. Travel and wireless communication have brought a rapid integration of the world and societal effects of this revolution are still to be seen. Blackmail and terrorism combined with media attention can have unexpected societal effects.

3.1 A societal polarisation

There are many possible causes for a societal polarisation. Difference in economic wealth between groups of people was one of the driving forces in the Bolshevik revolution. Religion is the dividing line between groups in the Northern Ireland. Reference to events far back in history has caused an unbelievable hatred between ethnic groups in former Yugoslavia.

Societal polarisation is aggravated by a loop of positive feedback when suspicions and rumour are believed more than factual evidence. The situation may escalate rapidly. Societal polarisation may ultimately trigger a local war which may escalate to a global conflict.

A societal polarisation does not necessarily restrict itself to a specific region, but it can distribute through subcultures in regions and countries. There are examples of extremist groups which have built up very rapidly.

3.2 Large cities

The large cities of the world represent a societal vulnerability of their own. Economic opportunities and a multitude of services have mounted large immigration pressures on the cities. At the same time they nurture many of the seeds of a societal polarisation.

Large cities are vulnerable with respect to their supplies such as water, food and electricity. The supply chains may be damaged by accidents or by sabotage. A break down of supplies may result in looting and unrest. Large cities are also vulnerable for the spread of diseases.

Large cities are characterised by an anonymity among its inhabitants which makes it easier for criminals and terrorists to hide. The sheer number of people promotes the emergence of various subcultures. The concentration of people and wealth in a large city makes it possible to live in them outside the ordered society.

3.3 Organised crime

Large economic gains can sometimes be made on activities condemned by the society. Narcotics for instance create a dependence by their users which is utilised by criminals through gratuitous introductions and increasing prices when the victim is on the hook. Narcotics have decreased the security in the society in large through increased violence and theft.

Organised crime typically controls narcotics, gaming, prostitution and protection. Organised crime has entered the weapons market and the transportation of refugees. Organised crime has made the laundry of money more common. There is some evidence that organised crime has engaged in dumping of hazardous substances.

Organised crime has a destabilising effect on the society as a whole. Organised crime may build connections to organisations which operate on the borderline to the accepted society. Networking and communication provide efficient tools making it possible for criminals to engage in global operations. Organised crime and terrorists may also join an unholy alliance for various ends.

3.4 Suppression of free opinion

Increasing violence and crime may create pressures for accurate monitoring of individuals. Modern information technology makes it possible to register almost any transaction of everyone. The possibility to build large databases and to combine information from several data bases may create a situation where people are watched practically with respect to everything. Automatic software agents can search for anomalies in behaviour patterns to imitate questioning by the police.

A transfer to increased monitoring may trigger polarisation between the established and an underground society. In such a development there is a possibility that free opinion will be suppressed. A suppression of free opinion is also likely to suppress necessary societal critics.

Societal stability is one of the crucial variables for building in a long term environmental concern into systems. Such stability is a precondition for many other long term considerations which may be difficult to ensure in a more dynamic environment.

3.5 Economics and the environment

Economic activity in a region gives the prime explanation for the overall level of emissions to the environment. For example a recent recession in Finland reduced SO_2 and NO_x emissions more than the systematic abatement measures had done. There are also examples where a local economic hardship has lead to exhaustion of scarce resources.

Experimental economics have shown that bubbles and crashes are common in a free market system. Historical evidence validates that assumption. If prices for commodities on a world market vary considerably it is likely that over-investments, subsidises and crashes may amplify the unstable economic climate. Economic instability has a tendency to spread through domino effects. Misery which may develop

in a region as the consequence of an economic crash can influence the environment in many ways.

3.6 Global instability

Local instability has a tendency to influence on a global level. Hardship in one region will introduce mobility of people which at some point creates the problem of refugees. Large populations of refugees are difficult to integrate in a society, due to real and imagined tensions which may be aggravated by suspicion and lack of communication.

A societal polarisation on a global level may create instability between regions and nations. Determination of local extremist groups can combined with the vulnerability of a technological society create a global hardship through sabotage and terrorism. Outside involvement in a local conflict can upset a delicate balance between competing groups in a region.

Available nuclear, chemical and biological weapons together with present delivery technology introduce a global dimension to any local war. Local wars can bring a heavy toll in environmental damage and increased societal instability.

4. A FRAME FOR RATIONAL DECISIONS

Models of a rational decision maker have been built using expected utility theory. According to the theory the utility of an outcome of a decision is weighted with its probability to give its expected utility. The normative decision rule is to select the option which gives the highest expected utility. Modifications of the theory have been made to reflect human preference for certainty and cases when the search for an optimal decision involves certain efforts.

4.1 Collection of data

Any rational decision making process relies on the availability of correct data. Most countries have their own systems for collecting national statistics. The collection methods have been harmonised to reach some level of comparability. Still there exists vast differences in the data produced and some countries have even been manipulating their own data for strategic reasons.

Some of the data for environmental monitoring can be obtained by direct measurements. Remote sensing and satellite imaging have improved considerably over the last ten years and such data can now give very good estimates of environmental conditions at various places on the earth.

The availability of data has also improved very much over the last few years. When it earlier was a tedious effort to collect and compile the numbers for various models, they can now often be obtained over Internet in a ready to use format.

4.2 Environmental threats

A rational management of technologies has to start with an identification of threats. Life-cycle analysis can provide information on emissions in various stages of production chains. Compartmental models of the environment give information on the fate of emissions to air, water and soil.

An awareness of possible problems can be obtained through actual observations, which means that then some impacts already have been realised. Observations from the environment have always to be supported with laboratory experiments to replicate interaction mechanisms and to estimate parameters. Sometimes experiments are required to establish levels of toxicity for species and substances involved.

When mechanisms of influence have been identified the question is, what kind of impact the emissions can have over the lifetime of a technology. Various kinds of growth models can be used to predict the development of a technology with time to give global estimates for emissions. In that connection one can also make assessments of possibilities for technological improvements with lower emissions and higher efficiency.

4.3 Societal threats

Societal threats can in the same way as environmental threats pose a challenge to system stability. Unfortunately available methods for identifying societal instabilities are not very reliable.

Large differences in the standard of living in a society tend to increase tensions. Ethnic groups with very different values which are interacting on a day to day basis may also create problems. An alienation of some subculture from the mainstream development may introduce social tensions which have global implications.

Instabilities on a global scale are the concern of many international organisations. The organisations have through their own models tried to create indicators of emerging problems. The shortcomings of such indicators are illustrated by present economic problems in the Far East.

4.4 Evaluation of action alternatives

A threat represents a risk through its probability and costs. The risk can be decreased through decreasing probability or consequences. Ultimately a technology can be considered to carry a so large risk that it has to be abandoned totally. This has been the case with nuclear power in some countries. Another possibility is to place strict regulation on the technology before it can be used.

Taxes on environmental emissions have been used to introduce an incentive to reduce them. One problem with this approach is that price elasticity for many commodities are rather small which implies that a heavy taxation has to be applied before production and consumption habits are changed. Taxes can also have a distorting effect on competition if they are levied differently in interconnected regions.

Because only limited resources are available one straightforward policy is to spend the largest efforts on reducing the environmental impacts which are the easiest to decrease. This thinking has introduced suggestions of introducing tradable emission rights where one party can get permission to continue emissions if he invests to prevent emissions from another party.

4.5 Calculation of possible outcomes

A calculation of possible outcomes requires accurate assumptions and good models. One difficulty is to assess the interaction between environment and society. Further no model can cover all aspects of environmental impacts of a certain technology on a global level. A practical approach is instead to use several models chained to give various part answers.

It is difficult to evaluate effects of various emission abatement policies. A very large number of consumer choices will influence supply and demand. Substitution between technologies can also have unexpected effects when relative prices are adjusted.

In an evaluation of feasible alternatives it is difficult to consider political consequences. A technically and economically sound alternative may be politically impossible to implement. Similarly there is always a political support of *laissez faire*.

4.6 Utilities and values

Outcomes should be connected to utility functions before decision on the best alternative can be made. There is a relationship between utility and value. This relationship is often fuzzy and can change from time to time. In most real world decision problems there is not a single utility, but a large number of sometimes competing utilities. Multiple utilities relate to multiple values according to which people form their preferences. A straightforward way to compare utilities is to convert them to a common utility such as money.

One difficulty is buried in the comparison of small and large costs. A direct comparison would for instance suggest that 1000 persons killed in one accident should be considered to have the same negative utility as one person killed in each of 1000 accidents. Societal decision making demonstrates however that these cases are not equivalent.

On a global scale it is necessary to differentiate between utilities in different regions and between different cultural groups. This becomes especially true when there are large differences in the standard of living such as between industrialised and developing countries.

4.7 Co-operation

There are always conflicts of interests between parties in a decision making situation. Conflicts of interest are often described in games. Completely opposite interest where losers pay winners, can be modelled as zero-sum games. Non-zero-sum games which exhibit a mix of common and conflicting interest sometimes evoke complex interactions between players.

Repeated play of the prisoners' dilemma which is a non-zero-sum game has been studied in various experimental settings. The game shows interesting characteristics in explaining how co-operation evolves.

It is in the interest of the society to promote co-operation. Individuals act in self-interest which means that societal rules should be instituted to give incentives for co-operation considered important for the society. Co-operation is facilitated through many public institutions. Such institutions are necessary for establishing common services in the society which otherwise may be impossible to fund.

Transfer of individual rights to societal institutions makes it possible to exercise power in a democratic system. Stability and trust are necessary preconditions for the functioning of such systems. In their absence a reliance on economic or military power might be the only remaining alternative. Bargaining and consensus building are still important components where early involvement of impartial arbitrators can have a positive influence on conflict resolution.

5. OBSTACLES TO RATIONALITY

Risks of damages to the global environment can be approached through rational decision making in a planning process. There are however many obstacles in implementing such a planning process. Even the dominant economic doctrine of a free market is in glaring contrast to the implementation of such processes. The obstacles have to be overcome in one way or another to decrease environmental and societal vulnerability.

5.1 Attitudes and practices

Mankind has always searching for limits of the possible. This has historically been done in a process of trial and error. This process has occasionally led to disastrous consequences. Earlier such consequences were local and did not challenge the life support platform of the earth. Things are now different, because errors with a global impact are not acceptable.

The second obstacle is connected to co-operation on a global level. Interest of the mankind has to be valued higher than individual, family or national interests. This need has been recognised, but a rapid adoption of such values is not very likely.

Democratic decision making processes present an obstacle to a global management of the environment. Decision processes are slow and geared to self-interest of local groups. Politicians are more interested in a second term in office than urgent and difficult issues. Traditions of democracy also seem to be young in many countries with difficulties to mobilise an understanding for its foundations.

5.2 Inaccurate models

A better understanding of mechanisms of global climate change is needed urgently. What are the consequences and what are the possibilities to abate the change? Without knowledge of low probability high consequence event sequences rational decisions cannot be made.

Another difficulty is connected to the interpretation of observations. It is difficult to separate weak development trends, because there are large amounts of random fluctuations in the time-series.

There is a need to identify sensitive subsystems and regions in the environment. An understanding of environmental resilience should be based on mathematical modelling rather than on experiments in the large.

One problem is connected to the complexity of interactions. It is not sufficient to understand the technical and environmental systems, but it is also necessary to understand of human decisions in groups and global politics. An integrated model of all those systems is not practical and separate mutually inconsistent models can give misleading answers.

5.3 Company practices

Large companies are today more environmentally conscious than some ten years ago. Many multinational companies have addressed values in their formulation of policies. Still there seems to be a long way to go before environmental issues enter the board rooms as something to be concerned with.

Small companies especially in the developing countries present a different problem. They are often using old production processes which are disastrous for the local environment. It is not likely that today's best industrial practices will dissipate very rapidly throughout the world.

Incentives to companies to adopt sound environmental management principles are mediated through various control mechanisms. These include regulation, taxes and subsidises. Consumer groups can put a pressure on companies through campaigns and boycotts. Industry can to some extent induce self-regulation. The power of these actions tend however to be rather small.

5.4 Accidents and incidents

It is important to design and operate production processes in the best possible way. Excellence in design can never compensate for poor operation, but good operation can sometimes compensate for a bad design. Production processes depend on an intricate web of technical, human and organisational systems which sometimes may interact in unexpected ways.

Good design principles have been developed to reduce human errors, but they are seldom applied systematically. Efficient feedback of operational experience combined with organisational learning are well established components of safe operation. High reliability organisations which for instance are used in air traffic and the nuclear industry provide examples of these concepts. Still it is astonishingly difficult to apply these observations into good management principles.

One important principle of high reliability organisations is honesty and openness. Unfortunately public media are very interested in dramatic accidents and speculations concerning individual responsibility. This has led to a situation where organisations in fear for negative publicity have closed themselves towards the public. This creates a tension which can-

not be resolved before media build similar quality control system as the industry concerned.

5.5 Defective strategies

A democratic decision making process relies on decisions made according to majority vote. Several voting systems can be applied, but according to a famous theorem there is no ideal voting system. Majority votes often govern decisions, but sometimes they may lead to majority dictatorship.

A phenomenon which can be interpreted as a reaction to polarisation in the society is the emergence of single issue movements. Many such organisations put environmental protection high up on their agenda, but select their actions on the borderline of the acceptable. Single issue movements have sometimes in protecting themselves towards critics adopted almost a military organisation where funding and decision making processes are shielded to the outside.

The step from serious single issue movements, through societal disobedience and violence to sheer terrorism is not very long. Psychological effects of placing young intelligent individuals in an opposition to more conservative forces may create a situation where antagonism is enforced through various positive feedback loops.

Societal decision making relies on negotiations and bargaining. Conflicts of interest are solved with compromises where compensations are paid by winners to losers. Conflicts of interests are often a reflection of different values. Such conflicts can be very difficult to resolve and they will often require international institutions as arbitrators Negotiation processes require investments in attention and resources.

6. TOWARDS BETTER MODELS

A better understanding of threats towards the global environment is needed. One part of this understanding can be obtained in building better models of how environmental systems respond to various emissions. The other part is concerned with an improved understanding of societal decision making processes. Finally the interactions between environment and society have to be understood.

6.1 The modelling process

There is a continuing need to get better models of various phenomena and systems. Models should be built on several levels of detail and models should be easy to connect to each other. That can be achieved by standardising model interfaces and data formats. Efforts of modelling have to be decreased below a critical threshold to make the use of models practical.

The art of modelling is a crucial component in the development of better models. This includes all steps requirements definition, selection of modelling scope, building the model, validating and interpreting obtained results. Building models require a good fluency in mathematics and computer science combined with a deep understanding of the subject science of the model.

The process of validation is crucial in developing better models. When experiments are used they should be repeatable, differences in experimental results should be explainable and assumptions should be open for critique. The value of model calculations tends to be small if they give results which are expected. Unexpected results have however the tendency not to be believed. A model that produces only mild surprises which can be explained is the best model in a practical sense.

6.2 Building for safety

The importance of building safety into technical systems has been realised for a long time. Early efforts covered ergonomic aspects of control stations and illustrated the necessity to bridge the gap between engineering and psychology. Present efforts include human decision making in the broadest sense combined with management and organisational issues.

Similar principles of ensuring safety of technical installations can be used in a broader sense. Mathematical modelling can be used to test system behaviour in advance. Simulators can be used for training and decision support systems to improve decision quality. Models are built and maintained to assess resulting safety. Operational experience is collected systematically, analysed and distributed to all actors. Regular bench-marking exercises are carried out to find possibilities for further improvements.

Inherent in safety precautions is the ALARP-principle (As Low As Reasonably Practicable) which means that risk reducing actions are carried to a point where a balance can be found between the achieved risk level and costs of further risk reductions. This principle could be applied on a larger spectrum of risks and to put them into a common frame. A cost benefit analysis of this kind would also be necessary as a basis for defining the relative merits of competing technologies.

6.3 Models of the global environment

There is a need for better models of various mechanisms which are important in understanding the global environment. Among the issues governing a global climate change are cloud formation, the carbon cycle, influence of SO_2, etc. It is not likely that all these phenomena can be covered in a single model, but separate inherently consistent model which are connected to each other can provide parts of an answer.

Among the models where a better understanding is needed is the prediction of causes and consequences of global climate change. It is necessary to improve an understanding of various mechanisms involved and to get a rough estimate of costs and probabilities involved. It is also important to get estimates of time constants involved. Only then it is possible to take a stand on the prudence of taking a gamble on that global climate change is a hoax.

6.4 Models of social choice

A democratic society relies on agreed processes for arriving at decisions. The processes should be built to reflect underlying values in the society. It is important to understand processes of value formation, because those will set preferences and choice both in the small and in the large.

Processes of defining of social values rely on a regular sampling of individual value functions through the expression of individual choice. Such sampling occurs in elections where individuals express their choice with respect to representatives in political race. Another way for individuals to demonstrate preferences is in buying products and services. Polls can also provide information on values.

Building models of social choice which can explain how values change over time is not an easy task. There is a demand for models which would enable political strategies to be formulated on a rational basis. Components of such models can be found in economics, sociology and political science.

6.5 Communication

Social processes of choice rely on the engagement of a majority for selected decisions and a consensus large enough for the minority accept them. This can be achieved only through communication. The communication should involve all aspects of decision making, models, value-formation, etc. The communication should be open and honest. Such a communication will require its own quality control.

One problem in the communication is the increasing complexity of the systems. It is common that only specialists have the deep knowledge necessary to understand central issues. In the communication it is important that confidence between specialists and laymen can be maintained. Expert panels of today have shown many examples where this communication has failed.

Communication should also be geared to the results obtained from various modelling exercises. It is necessary that the assumptions of these models can be made understandable for larger groups of people especially if the models will provide the basis for expensive decisions.

6.6 Finding consensus

Finding consensus both on the validity of model calculations and the actions necessary will be crucial. This can be found only if there is a trust between experts and laymen. A wide spread understanding of science and technology will also be crucial.

The level of basic education in the society will be a key to successful communication and consensus. It will be increasingly important to teach students to think. That will also help in fighting increasing beliefs in various pseudo-sciences. There will also be a need for continued education and an application of the concept of life long learning.

In democratic systems it may be necessary to create some form of larger consensus which means that winners of a vote to a reasonable extent takes into account views of the loosing minority. If such a tacit system is built into the society it is easier to ensure a sufficient stability of institutions.

Many of the issues concerning a management of global resource have an ethical dimension. The difficulty of solving ethical issues is that they are coupled to values where no absolute value scales exist.

7. A NEW WORLD ORDER

There is an increasing acceptance of the fact that the resources of the world are restricted. An increasing number of people are willing to make a contribution for a better world, but very few are willing to make major sacrifices to their standard of living. This is an impossible equation to solve without global institutions which have power to influence the sharing of resources.

7.1 Ensuring environmental friendliness

It will be increasingly important that environmental impacts are considered in all phases of a product on its path from cradle to grave. A life-cycle analysis in an early stage of the application of a new technology can help in the identification of potential problems and direct efforts in a search of better solutions.

Large scale applications of new technologies should be preceded by experiments and pilot scale demonstrations. Regular environmental audits including comparison with best practices can help in a systematic improvement of production processes. Support for ensuring environmentally sound products and production processes can be obtained through certification processes where products are marked for their environmental friendliness.

7.2 New accounting models

Decisions have to be made based on correct data. Various statistics has to be collected in a consistent way. Present statistics is not good enough and many of crucial indicators are misleading. For instance the calculation of the gross national product (GNP) does not take into account the environmental state of a country. That means in principle that economic activity in both polluting and cleaning up the environment will increase the GNP, but without a real contribution to the well-being of the country.

There is a need for creating macro-economic indicators to make an assessment of the state of the environment in a country. Only in that way it is possible to create economic counter-forces for balancing incentives to exploit natural resources which may have a global importance. Investments in environmental protection can in this way be given correct credit.

A number of well defined performance indicators can make it easier to make comparisons of performance between countries. The exploitation of certain natural resources could then for instance be coupled to simultaneous improvements of industrial efficiency.

Methodologies for environmental impact assessments have got accepted forms. By expanding the methodologies to consider mass and energy flows on a global level it would be possible to create instruments for better resource management. By providing the models with interfaces to run different scenarios of "what's if" questions it should be possible to put such instruments in the support of decision makers.

7.3 Global legislation and agreements

There is a need for international harmonisation between national legislation and regulation. Difference in for instance taxation has a large impact on economic forces by which competition between regions and technologies are solved. A recent example from the interconnected electric grid in the Nordic countries demonstrated how electricity from old coal fired units in Denmark substituted electricity from similar more environmentally friendly units in Finland.

There is a common understanding that environmental issues are important, but it can be very difficult to agree on actions. The recent environmental summit in Kyoto was able to reach only modest compromises on a reduction of emissions of greenhouse gases.

Exploitation of natural resources or new technologies should be based on prudence. Environmental impact assessments should be required for all major projects. The recycling of materials should be a special concern which could be promoted by levying a tax on the extraction of raw-materials.

7.4 A set of actions

The most important action in decreasing environmental and societal vulnerability is to initiate various systems, which have a stabilising effect. It seems also clear that some binding global regulation will be needed. It would be necessary to find methods by which the externalities of environmental damage and societal instability can be included in the price of products.

The economic system contains another source of instability. The break down of the planned economies may create a conviction that market economy with minimal societal interference is the best of possible economic system. The free movement of capital around the world creates however problems in ensuring planning and farsightedness. A small tax on capital movements may introduce a necessary dissipativity into the system to ensure short term stability without disturbing long term balances. Without regulation and economic disincentives it is likely that capital will move to regions where larger exploitation of the environment is allowed.

7.5 New institutions

There are many actions to be initiated before environmental and societal vulnerability can be decreased. The first step is perhaps to appoint a panel of experts like the international panel on global cli-

mate change. This panel could identify some of the most urgent issues and propose actions.

There is a need for global institutions which can engage in resolving conflicts which have an environmental dimension. To succeed such institutions should be able to exercise power for instance through economic sanctions. Decisions on sanctions have to be transparent and accepted by a majority of countries. There is a need for independent arbitrators who can lead negotiations when disagreements occur.

There should be institutions which can influence the exploitation of global resources by regulation and taxes. There should also be systems to assess the impact of new regulation, because regulation can, if applied in a distorting ways, easily have counterproductive results.

7.6 Setting a research agenda

There are many open questions in transferring towards a global resource management. Still this development seems to be necessary for avoiding risks of environmental degradation and societal instability.

Mechanisms of interaction between environment and society are poorly understood. A research agenda splits into two major directions, the first is involved in modelling the global environment and the second in modelling social interactions on a global level. Research efforts have to be decoupled from national interests to achieve credibility. There are international research institutes which may be interested to engage themselves in these questions.

Decision making will to some extent compare "apples and oranges". In a globalisation of the world it will be important to agree on the proposed research agenda. This is possible only if there are efficient communication processes between countries and cultures.

8. CONCLUSIONS

Mankind has entered a path of reliance on technology. This path has brought an unprecedented wealth to mankind, but it has also made systems vulnerable to disturbances. Due to the interconnectedness of the systems small disturbances may have global impacts. The reliance on technology has been an irreversible process which means that present problems can be abated only by further application of technology.

A global view on the utilisation of resources seems to be the only way of steering the world between the Scylla of environmental destruction and the Charybdis of societal instability. A society governed by an emotional approach to technological risks cannot respond in a balanced way to needs and opportunities.

Many steps will be needed on the path towards a new world order. In that process a better understanding of global decision making, negotiation and bargaining is needed.

Research efforts in technology, economics, environmental science, psychology and sociology have to be combined to create new models for how resources can be managed in a global world. The considerations will also involve the resolution of ethic issues and communication on a global level. Problems unknown today may however present even larger challenges for the future.

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