

Stockholm+40: Partnership Forum for Sustainable Development¹

– Scientific Background report on Sustainable Innovations, Production and Lifestyles

2012-04-18

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1. Introduction: Rationale, Purpose and Structure

This report has been commissioned by the Swedish Government/Ministry of Environment's request: The general purpose is to inform the Stockholm+40 international conference on sustainable living and innovative solutions held in Stockholm April 23-25 2012. The specific purpose is to look back at the prevailing scientific knowledge and the political processes pertaining to environment in 1972, the subsequent developments in research, knowledge generation, policy formulation and implementation, and future challenges. The report builds on scientific evidence but is deliberately written in a format and style, which can be accessed and understood by a broader target group than scientists, e.g. planners, analysts, development practitioners and decision-makers.

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The report is structured as follows: Chapter 2 introduces the Stockholm+40 conference topics ("Sustainable Innovations, Production and Lifestyles") by taking a historical look at environmental research and environmental policy work since the UN conference on the Human environment in Stockholm in 1972 and changes which have taken place since then. The report then addresses key policy developments over the 40 years, introduction of concepts such as sustainable development, and trends and research on sustainable innovations, sustainable production and sustainable lifestyles, respectively. Regarding **sustainable innovations** (Ch. 3) the report presents and discusses technical, institutional, organizational, economic and social innovations which have promoted sustainable development, and trends challenges and needs for new innovations to alleviate environmental pressures and find solutions. Other specific issues addressed include incentives for sustainable innovations to develop or reach new markets; legal incentives for sustainable innovations (rules, standards, norms, quotas), R & D (patents, intellectual property rights), and creation of/access to new markets for innovations, and economic, market-based incentives (fees, taxes, subsidies, levies, refunds) as new forms of incentives for innovations.

Regarding **Sustainable Production** (Ch. 4) the report presents trends in production, explains research knowledge on the production-growth-environment dynamics, with a focus on the scale effect, the technique effect and the composition effect. It briefly introduces and discusses concepts such as decoupling and the rebound effect, and addresses the role of government (policy instruments to promote Sustainable Production), institutions and the business sector for sustainable production and sustainable value chains – from local production to consumers, to reduction, reuse, re-engineering and recycling.

Regarding **Sustainable lifestyles** (Ch. 5) the report presents changes in lifestyles and addresses what is needed to promote sustainable lives and sustainable choices (the individual perspective), and presents trends regarding lifestyles, specifically pertaining to consumption of goods and services, transport, energy use and food consumption. This section ends with identifying and discussing

challenges to implement sustainable lifestyles, and ways to reduce/reform non-sustainable consumption towards sustainable choices.

The report ends with a **Summary and conclusions** (Ch. 6), which includes a broader discussion on lessons learnt and challenges which have to be met appropriately in order to promote and ensure sustainable development.

Caveat: By necessity a report of this brief format, broad scope, as well as the limited time in which it has been produced, implies by necessity that it does not cover everything in any detail or with sufficiently significant depth. Nevertheless it is the authors' hope that the report can inform readers on the developments which have taken place in the area of environmental sustainability over the last 40 years, that it adequately points out key challenges ahead, and inspires action.

2. Environmental Knowledge, Perceptions and Policy development in 1972 and onwards

At the UN conference in 1972 the interest in environment was in its infancy. The society had just become aware of that an uncontrolled industrial development, use of energy and release of wastewater and waste were causing effects that were threatening man and the environment. The interest in taking far reaching action was at this time still low. Environmental problems were often considered as a natural consequence of the modern society.

But there were alarms and a much more loud-speaking opinion had started to make its voice heard. The most important wakeup was probably caused by the American journalist Rachel Carson's book *Silent Spring* that was published 10 years earlier. The severe effects of the uncontrolled use of DDT that she pointed at caused an intense debate in the industrialized world and formed a deeper engagement in environmental issues both politically and among a wider public. But there were other alarms such as the poisoning of the population in Minamata, Japan, due to industrial release of methyl mercury.

Much of the focus at the UN Conference was given to the report *Limits to Growth* prepared by a group of scientists (Meadows et al, 1972) on request of the Club of Rome. The group pointed to the risk of large global problems within a few decades due to the ongoing increase in population, economic growth and exploitation of natural resources. The report had large influence on the societies around the world and was a strong driver for the development of environmental movements. The report formed a basis for discussions and further research on deforestation, overexploitation of agricultural land, water scarcity and the limitations of unsustainable exploitation of fossil fuels.

Even if the UN Conference tried to take a broad approach on the environmental problems, legislation and interests in environmental control were to a large extent directed towards the most polluting industries using end of pipe technologies, and in particular those pollutants that caused visible and nuisance problems. To exemplify, Sweden had prepared a case study on acid rain, but the meeting took hardly notice of this new problem that became a main international policy issue just 10 years later.

In Europe as well as in North America, energy production, in particular from coal burning were not subject for emission control until after 1980. Large control programs started in West Europe in the 1980ies and from 1990 significant emission reductions started in East Europe and North America. The control of emissions from traffic took also some time before it started. Even if regulations on cars were initiated in California at the end of the 1970ies, Europe-wide far-reaching legislation did not come in place until 1991. An important role in the work on emission reductions played the Convention on Long-Range Transboundary Air Pollution through which countries came together for negotiating on emission control but it also formed a basis for scientific and technological exchange.

About 1990, the view on environment shifted from mainly looking at control of pollution sources to also include the whole product chain; the society started to look at the overall impact from the whole product chain; life cycle analysis became a common concept. Forward looking industries played a central role in this development. The work was also linked to the concept of sustainable development - a concept that was an outcome of the Brundtland Commission and its report *Our Common Future* in 1987 (WCED, 1987). Through the Commission, initiated by the UN, the environment became visible on the global scene again and the importance of linking environment with social and economic development became a key issue for the future. The Brundtland Commission identified the three main pillars on which our common development should rest; economic growth, environmental protection and social equality. The report was particularly relevant and urgent for the developing countries with strong interest in reducing poverty, increasing living standards and become modern industrialized countries. In their commitment and efforts to develop quickly there was an obvious risk that they might attain economic growth via depletion and degradation of environmental resources and unethical labour practices.

The Brundtland report formed a basis for the Earth Summit in Rio in 1992. The meeting in Rio is probably the most important environmental conference so far. It included participation of some 170 countries and more than 100 of the countries were represented by the heads of state. Among important outcomes were the Rio Declaration on Environment and Development, Agenda 21, the Framework Convention on Climate Change (UNFCCC) and the Convention on Biological Diversity (CBD). The 27 principles in the Rio declaration include some basic principles for sustainable development including the right to development, the eradication of poverty, the protection of ecosystems, capacity building for sustainable development, public participation and the precautionary principle. The decisions at the Rio Conference opened for a new global agenda and decisions directed towards key environmental and sustainability problems. The decisions under the UNFCCC and CBD are certainly among the more important outcomes of the Rio summit.

Even if the global dimension of environmental problems and the exploitation of natural resources were recognized in 1972, limited policy progress was made in terms of control and common global actions until after the Rio Conference with the exception of one particular issue; the threat to the stratospheric ozone layer which was recognized already in the beginning of the 1970ies. But even if the problem was recognized at that time it was not until 1985, when the ozone hole was observed over Antarctica, when the problem was fully realized and serious actions were taken. These actions, primarily through the Montreal Protocol, have led to an almost complete ban of CFCs and other softer ozone-destroying compounds. This example shows that the society and in particular the industry can respond to environmental threats very quickly, and - through technological

development, political commitment and appropriate institutional and legal mechanisms - solve even global problems.

Climate change was also not recognized as a problem for international action until after the publication of the Brundtland report. In 1988 the Intergovernmental Panel on Climate Change (IPCC) was established as a vehicle for collecting and evaluating scientific evidence of the problem, its causes, effects and measures to both meet climate changes and to reduce emissions of greenhouse gases. The Framework Convention on Climate Change (UNFCCC) was created in 1992 and with these two bodies the climate change became an issue of global concern.

Over the last 10 years the overall industrial development has put much larger attention to environment. The environmental interest has become evident within almost all sectors. One sector that has received particular attention is the building sector, where large benefits can be reached with respect to energy savings.

The world has changed dramatically over the 40 years since the Stockholm Conference in 1972. The clear division in developed and developing countries is not so obvious any longer. Many of the poor countries have become industrialized; a larger share of the world's population now live in cities, access has increased to social and medical welfare, and relatively less people are subject to hunger. Some of the most urgent problems are gone but some of the largest are still without solution. The world is today more urgently in need for new solutions to problems such as climate change, overuse of natural resources and release of toxic chemicals threatening man and environment.

Future challenges

The society today stands at crossroads. Increasing populations and economic growth increase the demand for natural resources and the pressure on Earth's ecosystems. Attaining sustainable production, innovations and lifestyles will require major changes. If the human development is to stay within an ecologically safe operating space (Rockström et al , 2009) and successfully meet the grand environmental challenges (Reid et al, 2010) – including e.g climate change, biodiversity loss, acidification of the oceans etc. - larger changes than those over the last 40 years may be needed over the coming 40. These changes will indeed need innovations, development of techniques and new industrial societal thinking, but also bold political, institutional and economic reforms. As indicated by the World Business Council for Sustainable Development (*Vision 2050*), a long-term vision and a new interest can be seen within many industries to take an pro-active role in this development; increasingly, companies and investors are taking advantage of the opportunities in in meeting future demands for sustainable food production, energy, transport, housing, infrastructure etc. However, vested interests and likely losers in this transition will resist the necessary changes. The political economy of attaining sustainable development is thus of utmost importance and there is need for benevolent leadership, in the political sphere as well as in the business sphere.

Challenges ahead thus include i) seriously address the major ecological pressures on the planet by ensuring the establishment of a cost-effective institutional framework to appropriately govern and fully implement the multilateral environmental agreements, ii) reform national and global economic policies in order to implement a green economy across all scales, iii) enhance the work across disciplines, sectors and boundaries, and improve the cooperation between key stakeholders in society including the private sector, governments, intergovernmental bodies, the scientific

community, and civil society, iv) integrate the international agendas (principally UNFCCC, UNCBD, MDGs and Rio+20), v) increase the industry's confidence in the international political processes, bridge the North-South divide in scientific and technological capacity, and demand stronger and more effective leadership on sustainable development in the world.

3. Sustainable innovations

Social, institutional and organizational innovations for sustainable development: In 1972, the Member states of the United Nations as well as the UN system itself lacked formal institutions and organization(s) to address the environmental challenges presented at the Conference. The Conference triggered work at the local, national and international level to deal with the challenges. Soon after the Conference, UNEP was created and became the most prominent actor at the global level responsible for addressing global environmental issues with a mandate *inter alia* to monitor environmental change, inform the world and promote action.

Since then a number of social, institutional and organizational innovations have been made to promote sustainable development. Research by e.g. Ostrom (1990, 2005), Williamson (2000) and Acemoglu et al. (2004) have shown the importance of institutions for sustainable development, and in particular that good institutions matter greatly for economic and democratic development, and social and environmental sustainability. Institutions pertain to formal "rules of the game" such as the judiciary and the government bureaucracy, defining rules, regulations and legislation, and governance ("play of the game") which includes contracts, aligning structures etc. The functioning of the institutions are to a great extent influenced by norms, trust, values, customs, traditions, social networks, and more formally by the quality of the formal institutions.

Innovations in this area essentially have mainly been attained through significant generation of knowledge, and partly based on that, reform measures which have transformed, and improved the functioning and quality of organizations and institutions to promote sustainable development. Over the years significant changes in both formal and informal institutions have been implemented. Formal institutions have been established to promote environmental management (and social and economic development) through the creation of ministries of environment (or equivalent) in most countries of the world, environmental protection agencies and other auxiliary expert bodies on specific thematic issues, e.g. chemicals, to monitor proliferation and suggest control measures. More generally, policies and legislation on the environment have been formulated and adopted, and national guidelines and systems for Environmental Impact Assessment (EIA) and subsequently Strategic Environmental Assessment (SEA), have been developed and used (Engfeldt, 2009; Dalal-Clayton and Sadler, 2005).

At the local level, social, institutional and organizational innovations for sustainable development include processes of devolution of rights and increased user- and/or ownership rights over natural resources and -management. Progress has been patchy, but a marked trend in developing and emerging countries is one of land reforms and various types of natural resource sector reforms, where (rural) communities or individuals have been entitled strengthened rights to use, own or manage surrounding environmental resources such as forests, water, grazing lands and fisheries. However, due to increasing pressures on these resources the devolution of rights has been

challenged, and sometimes reversed, by other stakeholders and vested interests, such as domestic and international companies, or actors in competing sectors.

Valuable knowledge has been generated on the role and potentials of community (or joint) management of common property resources and public goods such as watersheds, water courses, wetlands and forests (see e.g. Ostrom, 1990, 2005). Many of the studied institutions by e.g. Ostrom were not new or recent innovations, most often in fact the opposite, but what they pointed at and revived, was the ability and opportunity among local communities to jointly and sustainably manage common resources, without (much) interference or control by the government, or the market. These insights indicated and informed policy makers and development practitioners about the possibilities to promote sustainable development by devolving responsibility for natural resource management to local resource users/managers, subject to certain conditions of conduct. These findings also provided arguments, and useful information, for subsequent design and use of novel economic/financial innovations for sustainable development, e.g. financing social/community-based forestry, and payments for providing ecosystem services such as biodiversity protection, watershed management and control of hydrological balances, and carbon sequestration in forest resources. In order to be successful, many of these innovations presuppose social/institutional/organizational innovations in the form of decentralized, community-based common property resource management schemes.

Economic and financial innovations for sustainable development: Since 1972 a number of economic and financial innovations have been developed and implemented to promote sustainable development. During the 1970ies and 1980ies the principal policy instruments deployed to manage the environment were of command and control- and information character. Emission limits were set for industries and people were informed about environmental risks and were urged to reduce energy use, generation of waste and behave responsibly vis-à-vis nature. These initial steps were necessary but insufficient. Following the findings within (environmental) economics, that it is usually more cost-effective to use economic instruments, in combination with other legal instruments and voluntary agreements, to promote environmentally sustainable behavior, a number of economic policy instruments were introduced in the environmental politics during the 1990ies. In mainly OECD countries it had started to become clear that using only rules, regulation, norms and standards makes it essentially free of charge (no cost) to pollute up to a certain permitted limit.

From around the time of the UNCED conference in Rio in 1992 it had become increasingly clear to governments that introducing environmental taxes and fees would be beneficial for the Treasury as well as the environment to make pollution and natural resource depletion costly. Hence introducing costs in terms of environmental fees, taxes, levies and tradable emission rights offered a powerful incentive, indeed a financial environment innovation, for the polluter - consumers as well as producers - to reduce pollution, and for the government to manage the environment with a new set of tools.

During the last 10-20 years these innovations have proliferated and become part and parcel of the international environmental governance system with a whole range of new economic policy instruments, nationally as well as globally (Sterner and Coria, 2012). Internationally these include e.g. tradable emissions permits (eg the European Trading System for CO₂ emissions), Debt-for-nature swaps, the Global Environment Facility (GEF), the UNFCCC Clean Development Mechanism (CDM), financing carbon sequestration in forestry via UN-REDD, environmental subsidies, Payments for

Ecosystem services (such as sustaining hydrology in watersheds through soil and water conservation), and other flexible financial mechanisms for reducing pollution and resource exploitation, or promoting environmental management via various financial incentives.

Innovations have also been introduced in the area of measurement and indicators. In particular in the areas of environmental assessment and environmental economic accounting some progress has been made. Examples include the World Bank's work on genuine savings, or environment-adjusted net savings, economic valuation of ecosystems and biodiversity, natural resource accounting, environment-adjusted ("green") GDP and identification of environmental debt at various scales. These initiatives have been helpful in measuring and tracking progress across a large set of countries or ecosystem services. To exemplify, the Millennium ecosystem assessment (MEA, 2005) and the initiative to identify economic values of ecosystems and biodiversity (www.teebweb.org) have – by pulling together expertise from various scientific fields and disciplines and communicating findings to the policy sphere - raised attention to the current state of key ecosystems, the economic benefits of biodiversity, highlighted the accelerating costs of biodiversity loss and ecosystem degradation and impacted on political processes, most notably the implementation of the UN Convention of Biodiversity.

Adjusted Net Savings: Arguably one of the most innovative measures to track environmental economic progress is the Adjusted Net Savings (ANS). This is developed as macro-economic measure to shed light on countries' sustainability across time. Adjusted Net Savings (ANS) builds on the work by Dasgupta and Mäler (1997) and Hamilton and Clemens (1999), and is used by the World Bank and other international development cooperation agencies to assess of change (accumulation/depreciation) in countries' capital savings. Formally, it is linked to gross savings, which is regularly reported in countries' National Systems of Account. However, current measures of gross savings do not include costs of environmental degradation or costs of natural resource depletion. Adjusted Net Savings adjusts for these shortcomings and subtracts costs of natural resource depletion for some resources (timber, minerals, oil, natural gas and coal), costs of local air pollution and CO₂ emissions (estimate of global damage cost). Conceptually, it is a very useful measure, but its usefulness is somewhat hampered by exclusion of the costs of some key environmental issues like soil erosion and land degradation, loss ecosystem services, over-fishing, over-grazing, increases in water scarcity and water pollution.

Incentives for sustainable innovations to develop or reach new markets: Incentives for sustainable innovations to develop or reach new markets may be *legal* (rules, standards, norms, quotas), or *technical*, typically in the area of Research and Development (R&D) and most often pertain to patents and intellectual property rights (IPR).

Regarding legal innovations, green public procurement has proven to be one of the most effective tools for pushing for sustainable solutions, products and services. This is accomplished due to the fact that the share of the market represented by green and socially responsible public procurement is significant in many sectors and important for other sectors. As a move to speed up sustainability goals, the European parliament has decided in October 2011 that all public procurement should include life cycle-cost criteria above the general criteria.

Enhancing the use of green standards offers significant opportunities to attain sustainability. To illustrate some of the potentials, the following examples may be considered: if the whole of EU were

to adopt new energy efficient standards for lighting and office equipment, operating costs would be reduced with 50% and CO₂ emissions cut by around 15 million tons per year. If the whole world were to use the most energy-efficient light bulbs, CO₂ emissions would be cut by around 190 million tons, which corresponds to approximately one fifth of the European target for reducing emissions of carbon dioxide by 2020. Another example is if the whole European public sector were to adopt the Danish Ministry of the Environment's guidelines for cars, CO₂ emissions would be cut by around 100,000 tons per year, fuel and operating costs by more than 30%. If all cars sold in Europe met these standards, CO₂ emissions would be cut by 220 million tons, more than 20% of the European target for 2020.

The environmental management standard 14001 uses the Plan-Do-Check-Act schedule. It is a management standard and not a performance standard. However, the management commitment and involvement, visualization of the performance and the third party audit create significant impacts in businesses and public organizations. The Environmental Performance standards in the 14030 series have not yet been well spread or implemented. However, the product and service standards on *eco-labelling* and *life cycle environmental performance* in the 14020, 14040 and 14060 series including Environmental labelling and declarations, Life Cycle Assessment (LCA), Carbon and Water Footprints have been spread, used and implemented widely in the market on a global scale. Harmonization of methods and standards has proven to enhance life cycle based criteria for purchasing and procurement, and provide useful incentives for green investments.

Business models and economic incentives: The collaboration between business sector and policy sphere is necessary in order to identify far-reaching technical and business model innovations, which increase business values *and* contribute to public policy objectives pertaining to sustainable development. One such business collaboration model is *Energy Performance Contracting* (EPC). EPC is a model for energy-efficient investments with longer pay-back time periods than what is ordinary required by banks and financial institutions. By creating a business model more adapted to the actual time periods, incentives are created and communities have started to take initiatives to undertake more long term investments and commitments (e.g setting more far reaching greenhouse gas emission reduction goals).

Many innovations are developed in order to reduce costs and facilitate for suppliers and consumers, and has as a side effect an improvement of the environmental and sustainability performance (IfM and IBM, 2007). Examples on such innovations are services such as call centers, internet banking, video conferencing, long-range electricity management and medical services, and optimized electricity demand and supply management tailored to accommodate e.g. peak pricing, low intensity period utilization etc.

Regarding the role of R & D for increasing access to - or creating new – markets, intellectual property rights (IPRs) key function as an obstacle for innovative collaboration until there are mature and stable systems to protect these rights. It is thus very important that governments and other public organisations create platforms or fora where these types of obstacles can be solved by jointly agreed “rules of the game” in order to speed up efforts to scale up and proliferate knowledge or technologies which have broad societal importance and are essential for global development. Obstacles of this kind have been experienced in the public health sector regarding the proliferation of vaccines and pharmaceuticals in poorer countries.

Social incentives for business-driven sustainable development: Increasingly, companies in OECD countries internalize social dimensions in their business model to attain sustainable development (societal goal) and attain their business-specific (private) objectives. In other words, social entrepreneurship is pursued by companies to combine company-specific profit maximization objectives with addressing specific social challenges. Often this starts small-scale at a local basis and is scaled up as companies grow. In Sweden evidence show that company-driven social entrepreneurship often has started with aims at increasing integration and decreasing socio-economic segregation and alienation. In the US, as well as in several other countries, social entrepreneurship has addressed social and environmental issues such as local water availability, poverty and climate change. Often these kinds of efforts end up being public-private partnerships – where governments or municipalities buy-in – pursuing jointly agreed social and environmental objectives benefitting the public. In the US, social entrepreneurship is increasingly labeled as ("profit" or "non-profit") *social impact investments*, with specific tax arrangement deals depending on the type of investment (Kerlin, 2009). To illustrate the scope and global potentials of these measures, it has been estimated that 400-1000 billion US dollars will be invested in this sector between 2010 and 2020, with the main goal to decrease poverty in developing countries. This figure is additional to the existing already mature, well spread and scaled-up financial sub-sector “Socially Responsible Investments” (Donohoe, 2010).

Economic, market-based incentives for sustainable innovations: Since around 1990 with a boost from the UNCED conference in Rio in 1992, several economic, market-based incentives where proposed, developed and to some extent implemented to promote sustainable development. In the area of public economics these instruments offered, and still offer, innovations to prevent environmental public “bads”, and promote environmental public goods and services. The market-based incentives mainly include fees, taxes, subsidies, levies, refunds and market-traded (pollution) permits.

Addressing these challenges will most likely require a mix of policy instruments, which allow for cost-effective implementation and flexibility (to prevent physical lock-ins). In addition to setting stricter standards, rules and norms for production, supply and management of energy, transport, buildings housing and infrastructure, water, fuel, food and fibers - to and within cities – there is a need for information, voluntary agreements, “contracts” between public-private spheres, optimized use of ICT solutions, but arguably most prominently stronger economic policy instruments; removing or gradual phasing out or harmful subsidies of natural resource-depleting and polluting activities (e g water, coal, gasoline), introduction of subsidies of environmentally benign activities in building and sustaining the cities, as well as taxes, fees, and levies, and review of tariffs on urban (public and private) goods and services (energy, transport, infrastructure, water, fuel, food etc.). Economic and market-based incentives for sustainable innovations: Reforming institutions and addressing the political economy issues of implementing these reforms is critical.

Challenges: Clearly, progress has been made during the last four decades and a large set of technical, social, economic, organizational and institutional innovations have been developed and implemented to prevent further environmental degradation, and to promote sustainable environmental management. However, current and future environmental challenges call for refining and finding new and novel innovations, in all fields of development. Key challenges ahead are to find ways and design/reform frameworks which can trigger development of these new innovations. Key policy questions thus include: what ways and frameworks can trigger development of new enhanced

innovations for sustainable development? What incentives and conditions are necessary to inspire development of new innovations? How can synergies across innovations be maximized to speed up policy implementation?

4. Sustainable Production

During the last couple of decades global growth in production of goods and services has been unprecedented. To exemplify, between 1990 and 2011 global electricity production has increased by more than 70%, livestock production with 47%, and food production with 45%. During the same period, production of cement, plastics and steel has increased with 170%, 130% and 100%, respectively. With the extraction and globalization of the supply of these resources, production (and consumption) has not only increased, but also changed in a transformative manner to pose new challenges to the world's ecosystems. This can be illustrated by the increased and changed land use: The area cultivated for palm oil has increased 120% during the last two decades. Land area for soybean production has increased 120%. Both of these processes have been driven by the increasing needs for fuel and food.

Reaching consumers, with the increased volumes of products, have been facilitated by a globalization of markets, exemplified by an increase in air freight transport by 230% 1990-2011. Intensity in resource use has decreased 21%, which indicates that relatively less resources are used to produce a unit of GDP. Resource efficiency has also increased in product design and production processes. Similarly, CO₂ emissions per unit GDP have decreased 23% since 1990. In sum, production – and in turn consumption – has become more resource efficient per unit cost or product, but due to increasing scale (powered by economic growth and an increasing global population) these *relative* gains have been obtained at the cost of increased *total* consumption or production. This is illustrated by the fact that global total CO₂ emissions have increased 39% since 1990, and total materials extraction has increased 41% during the same period.

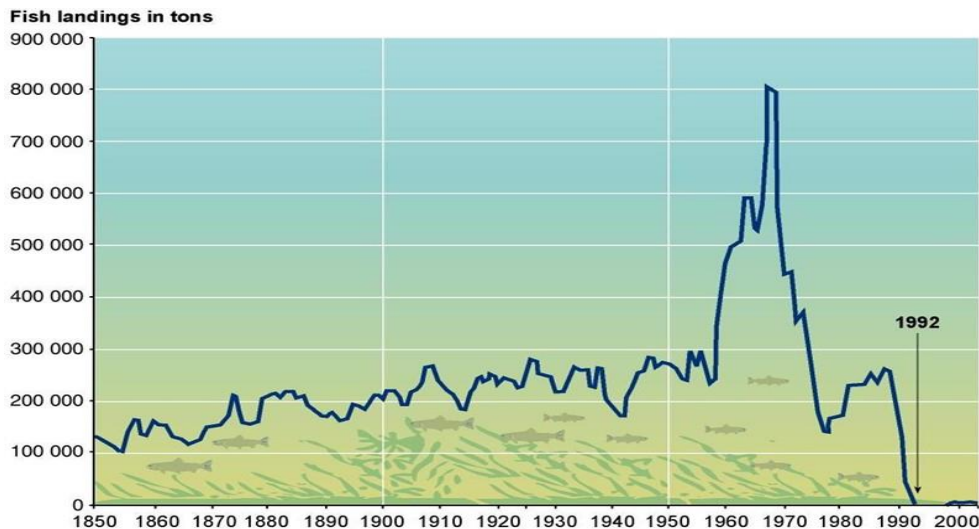
The production-growth-environment dynamics

The natural environment plays two key roles in relation to production of goods and services and economic growth. First, the natural environment provides natural resources, which function as inputs to the production of goods and services. The inputs can be direct or indirect. Second, the natural environment functions as a sink to pollutants which are generated from economic production and consumption. Examples include hazardous air, water and solid pollutants which are dissipated in the natural environment, which is also a repository for solid and toxic waste. Within certain ecological limits, the natural environment has some absorption capacity of external pollution.

When the functions of the natural environment are seriously impaired, the productive capacity is seriously hampered and economic growth can slow down or even be negative. This is the case when abundance or access to natural resources decline rapidly or in absolute numbers over time. This applies for instance when stocks of fish, forests or minerals are being depleted, or when nature's capacity to absorb or dissipate waste and pollutants is exceeded and when environmental quality is reduced. Production may also decline or be hampered by due to policy responses which prohibit certain (components, materials, toxins in) goods, or imply costly investments in pollution abatement

or mitigation technologies. Production may also be hampered due to irreversible effects on nature's ecosystems and the goods and services produced by them. This is most vividly illustrated by the decline in cod landings in north-eastern Canada as an effect of over-fishing across time in the area.

Figure 1. Collapse in cod fisheries off the East coast of Newfoundland in the Northern Atlantic Ocean



Source: UNEP/GRID-Arendal. (2005). Collapse of Atlantic cod stocks off the East Coast of Newfoundland in 1992. UNEP/GRID-Arendal Maps and Graphics Library. Available at: <http://maps.grida.no/go/graphic/collapse-of-atlantic-cod-stocks-off-the-east-coast-of-newfoundland-in-1992> (accessed April 2012, permission granted by UNEP/GRID-Arendal)

Moreover, economies specializing in less pollution intensive services or relatively less natural resource intensive industries can at best delay the impact of binding environmental constraints. In the short run these constraints are met through substitution of clean inputs for dirty ones, increased abatement or new technologies. However, in the long run, emission intensities must fall towards zero if growth is to be sustainable. Sustainable growth is often defined as increasing or non-declining environmental quality and natural resource depletion and continuous growth in per capita income (Brock and Taylor 2005).

It is clear from the research literature that beyond the basic links between economic production and environment, the links between economic growth, environment and climate change are highly complex, multi-dimensional and dynamic, with inter-linked ecological and human-induced (economic, political and social) feedback effects. Despite decades of research there is no consensus on how production, growth and environment are linked and what factors determine what. This is partly due to lack of adequate data and empirical evidence, and too short time series to allow robust relationships and credible projections. There is still considerable scientific uncertainty characterizing the debate, for instance on the functional relationship between certain air and water pollutants and economic growth, between climate change and economic growth, and between natural resource exploitation and economic growth. Some of the literature represents a "increased-production based growth optimism" with respect to the impact of increased production and growth on environmental quality (largely relying on technology innovations and technical development) and the prospects of attaining environmental sustainability, whereas others find evidence for "growth pessimism", i.e. that increased production and economic growth indeed harm the environment, in the short and/or the long run.

Despite the different perspectives on growth and environment, some general patterns – which are based on analysis of pollution data covering a couple of decades of annual measures and a large cross-section of countries in the world – have been identified: Emissions of some health-threatening regulated pollutants² have declined along with rising production and national incomes in several OECD countries. To exemplify, data of US emission intensities between 1940-1998 indicate that emissions per GDP of particulate matter (PM₁₀) fell by 98% over the period, emissions per GDP of SO₂, volatile organic compounds and carbon monoxide fell by around 90% and NO_x emissions fell by 60%. Research also indicate that the cost of pollution control to attain the current environmental quality levels have been relatively small, approximately 1-2% of GDP per year for OECD countries (OECD 2003). Grossman and Krueger (1993, 1995) represent early research which identified that emissions of some pollutants show an inverted U-shaped (non-linear) relationship with rising income across time.

Subsequent research has raised some doubts about the existence of a predetermined curvi-linear relationship between certain pollutants and conomic growth; and, consequently, whether it makes economic sense to postpone environmental investments until certain growth and income levels are attained (as some have argued). Important caveats which have been raised in relation to the data and interpretations raised above are that data showing falling pollution intensities (pollution per output unit) and reductions in total emissions often mask the fact that pollution concentrations (in soils, air, water) for some pollutants have increased due to cumulative effects despite economic growth. Cross-country studies also show that relationships between economic growth and pollution emissions differ substantially among countries. For some pollutants and for some countries there is evidence of an inverted U-shaped curve, but its existence locally does not imply that it is predetermined, predictive or a robust relationship on a larger scale and across time, and it should not be translated to all forms of environmental pressures. For instance, generation of solid waste increases in absolute terms with income, in some cases near linearly, in others exponentially with accelerating waste generation as incomes grow across time.

Recent research has gone beyond the statistical artefacts which may indicate a certain functional relationship between growth and environment and showed that several political economy and governance issues are key determinants to the final outcome for a certain country's growth path and environmental quality. Importantly, many growth-environment relationships have been partly explained by countries' different public environmental policy decisions and environmental management regimes governing production and pollution (Zugravu et al, 2008). Another explanation is found in the difference in inequality across countries; income inequality produces a gap between the country's ability to pay for environmental protection and a country's total willingness to pay (Magnani, 2000). For many pollutants the time series data is rather short (30-40 years) and of varying quality, which contributes to the difficulties in making any reliable predictions for the future. Fredriksson and Svensson (2003) have showed the importance of political (in)stability and corruption for environmental management; political stability has a negative effect on the stringency of environmental regulations if corruption is low, but a positive effect when corruption is widespread. They show theoretically and empirically that corruption reduces the stringency of environmental regulations, but the effect disappears as political instability increases.

² Sulphur dioxide (SO₂), nitrogen oxides (NO_x), volatile organic compounds (VOCs), carbon monoxide (CO), particles (PM₁₀)

It is not possible to state a priori whether growth is bad (or good) for the environment without further qualification. This is largely due to the fact that the production-growth-environment dynamics is subjected to scale, technique and composition effects. First, “environment” has to be defined, typically according to some pollution-, resource scarcity-/depletion-, or sustainability measure. Second, the outcome on the environment depends on the (change in the) characteristics of the production process and the products as such, as well as the type and sources of growth. Some economic growth is based on investments and production, which *reduce* pollution and natural resource use. Indeed, other economic activities contribute to produce the opposite result. Irrespectively, production processes, products and economic growth have all been an important drivers of environmental change, where research show multiple evidence of negative impacts on the global environment and its ecosystems, often caused by increased global trade during the last couple of decades (Millennium Ecosystem Assessment, 2005). Research on growth and environment has identified three important effects, which operate as production increases and economies grow and have bearing on countries’ change in resource use and pollution across time - the scale effect, the technique effect and the composition effect:

The scale effect: The scale effect refers to the scale of economic activity and relates to the use of natural resources in production and the pollution impacts of production. Research shows that if production of goods and services consumes natural resources and produces pollution as a negative side effect of it, then increasing the scale of the economy will – everything else equal – increase resource depletion and pollution. Hence, for purely physical reasons increasing the scale of the economy will degrade the environment. However, products, production processes and production technologies do not take place in isolation. Production is dynamic and responds to new pressures, constraints and opportunities. Hence, production in growing economies are not only increasing in scale they also trigger changes in the technology and composition or structure of the production (Dean, 2002; Brock and Taylor, 2005). This produces the technique effect and the composition effect.

The technique effect: Economic growth facilitates technological progress in production of goods and services. This technique effect implies cuts in emissions per produced unit as well as reduced natural resource (and energy) use per output unit. Also, increased abatement creates a technique effect in terms of lowering emissions per unit of output, but may also lower pollution by lowering the growth rate of output. Early investigations on environmental limits to growth (e.g. Meadows et al, 1972, Club of Rome), under-estimated this dynamic effect in liberalized, competitive and open economies where recycling and substitution into new materials represent strong technological feedback effects, which counter-act the scale effect, reduce pollution intensity and reduce natural resource demands in the production.

The composition effect: Industrial development across time shows that growing economies specialize in less pollution-intensive goods and services and/or relatively less natural resource-intensive industrial production. Combined with the development of more pollution intensive production of goods and services in developing countries this has fuelled research and debate on the “export of dirty production” from rich to poorer countries. Combined with relatively less strict pollution regulation in developing countries it has also triggered research on the so called pollution-haven hypothesis.

Research has investigated the net effect of these effects in search for the absolute and relative contribution of these effects to impacts of growth in production on environmental change (resource use and pollution). Behrens et al (2007) show that annual natural resource consumption of the World economy (i.e. countries' domestic natural resource extraction) increased by about one third between 1980 and 2002. This indicates that the scale effect outweighs the other effects. Over the same time period, the World's material intensity (resource extraction per unit of GDP) decreased by about 25%. This result indicates relative decoupling of resource extraction from economic growth at the global level. A general conclusion from research on growth in production and environment is that there is no predetermined "natural" path or functional relationship (e.g between a pollutant and GDP/capita), which is followed. Technical and organizational innovations, consumer preferences and lifestyles, environmental policies and management play key roles in determining the outcome. Similarly, countries' level and quality of governance, corruption and institutions also constitute important determining factors (Fredriksson and Svensson, 2003; Zugravu et al, 2008; Magnani, 2000).

The role of the business sector for sustainable production: Increasingly, the important role of the business sector for sustainable production and sustainable value chains has been acknowledged by governments and in international fora. Work by e.g the World Business Council for Sustainable Development has contributed to this work and somewhat changed perceptions of the role of the private sector. Clearly, the business sector worldwide is part of the problem, and a major driving force behind pollution and natural resource depletion, but also - and necessarily - part of the solution.

The business sector, which includes small- and medium sized enterprises as well as multinational companies, increasingly understand and acknowledge the need to incorporate environmental factors in their business strategies, production and cost and revenue structures. Due to climate change and other environment related risks and uncertainties they have to plan for the unexpected. Due also to the fact that they are operating in an increasingly interconnected and globalized market, with production and supply chains stretching across continents, they are highly vulnerable to environment-related disruptions. Key functions which may be played by the business sector include technical innovations for sustainable production and sustainable development, energy and resource efficient products and operations, sustainable supply chains, and strategic (public-private) sector partnerships. Other functions the business sector have and where they have a key role to play to promote sustainable production, is to find and use ever more cost-effective methods to reduce, reuse and recycle natural resources.

Challenges: Challenges ahead include reducing the negative scale effect on the environment of increasing production levels. This is not a small task given the driving force of global demand for goods and services and the underlying economic growth. Nonetheless, reducing the scale effect essentially implies reducing the total pressure on the planet, and reducing the ecological footprint of those producers (and consumers) – countries, companies, citizens – who currently places the heaviest and unsustainable burdens on the planet. Linked challenges include promoting/attaining absolute de-coupling of economic growth from increasing environmentally harmful production (and consumption), and avoid increasing pressures created from the rebound effect of increasing technical efficiency in production. Gains in efficiency must not be followed by increasing the *scale* of production (thanks to lowered per unit-producer costs/-prices) by increasing the *total* pressure to critical levels (i.e prevent/minimize the rebound effect of the efficiency gains).

Another challenge pertains to the need to dramatically raise – globally - the levels of recycling and re-use of scarce materials or resources, re-engineering of old products or production processes (to reduce pollution, resource and energy use), phase out of hazardous waste and materials, and substitution of materials and technologies, which can reduce the use of e.g. fossil fuels and rare-earth metals, and reduce the pressure on vulnerable ecosystems. Production cycles and processes must to a larger degree “close its loops” and reduce the generation of waste, by conducting life cycle assessments of the production processes, and adhering to more stringent Environmental Management Systems. Several policy instruments may be used to attain these activities (Sterner and Coria, 2012).

Different strategies and attempts to address these challenges are explored. For instance, EU suggests in *Roadmap to a Resource Efficient Europe* (European Commission, Brussels 20.9.2011) that costs of natural resources extraction, pollution and other externalities are internalized in prices through green taxation. It also suggests that inefficient subsidies are phased out.

Japan pursues an “elements strategy”, which aims at preventing future resource scarcity problems, by creatively combining and making more use of elements that are abundant (materials substitution) and therefore reduce the pressure on scarce material resources. Specifically, the Government of Japan has drafted a bill requiring consumers to recycle used electronics containing rare earth and critical metals. Evidence indicates that this is likely to be a major challenge globally as several sectors and countries invariably have increased the demand for these resources to sustain or increase production and product supply. This is particularly true for electronics but also other high-tech sub-sectors. Rare earth metals and other critical elements will most likely continue to be high on the agenda as demand is maintained. Hence, increased global collaboration will be necessary to harmonize rules and codes of conduct, promote sustainable supply chains and close the loops of the materials management systems. It is also necessary to avoid leakage (of rare metals in electronics and high-tech waste) to countries with lax environmental legislation, and substitute rare metals for more abundant elements.

5. Sustainable lifestyles

Finding ways to live sustainably and making individually sustainable choices are key to attain sustainable development. Generally, there is a strong relationship between lifestyles and environmental change, principally determined by the number of people in any given environment and the way in which they live. Consumer behaviour is thus strongly determining the impact that the individual has on the environment. Hence attaining sustainable lifestyles requires an understanding of consumer behavior, consumption patterns, trends over time and incentives to change consumer behavior and lifestyles towards sustainability.

Over the last 40 years we have seen dramatic changes in lifestyles and consumer behavior. In short, at the global scale, we consume more, are more mobile, travel longer (to work and during leisure time) and more often, and are increasingly part of a global digital network, boosted by increased connectivity and rapid spread of mobile phones, computers and the Internet. The digital revolution has shaped consumer behavior profoundly and rapidly, arguably more than any other technological development during the last couple of decades. It has created new markets and new habits, and

transformed old ones. To exemplify, since the Rio conference in 1992 mobile phone subscriptions have increased with 23,000 %; the number of Internet users have increased 29,000% since -92, reaching 2 billion people in 2010. India and China together added 200 million mobile phone subscribers in 2010 alone.

Resource use has grown faster than the population during the last couple of decades. Since 1992, world population has grown with 1.5 billion people to reach 7 billion people/consumers in 2011. Over 1 billion people have moved into cities during the last two decades, and due to increasing incomes people have adopted more resource intensive diets and lifestyles.

Figure 2. Global Consumption Change 1990-2011 (%)

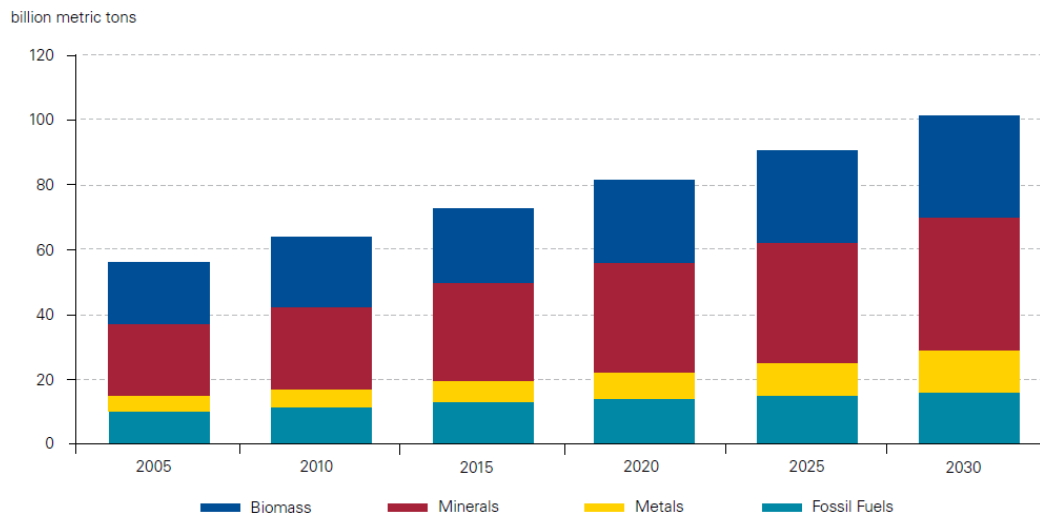
Consumption type	% change	Consumption type	% change
Nitrogen fertilizer use	135%	Coal consumption	45%
Construction materials use	80%	Natural gas consumption	45%
International tourist departures	73%	Fish and seafood consumption	32%
Total energy consumption	47%	Petroleum consumption	30%
Meat consumption	26%		

Source: UNEP, World Bank, Worldwatch Vital Signs, WWF, SERI, UNDP, FAO, IEA.

As indicated in Fig 2 global consumption has increase dramatically in a number of areas (“consumption types”) with profound impacts on global pollution levels and natural resource use. To exemplify, as shown in the figure, nitrogen fertilizer use has increased 135% since 1990, coal consumption has increased 45%, consumption of natural gas, energy and petroleum has increased with 45%, 47% and 30%, respectively. As an indicator of our global increase in global mobility, international tourist departures have increased 73% since 1990. Regarding food, we have increased our consumption of meat and fish and seafood with 26% and 32%, respectively.

Compounded, the per capita natural resource consumption has increased 27% during 1990-2011, and the global ecological footprint has increased 27% during the same period. This is unprecedented in the human development. These changes have been facilitated by major increases in production (ref. chapter on Sustainable production). And the increase will continue. As shown by figure 3, projections on future global resource extraction (until 2030) indicate that the global needs for biomass, minerals, metals and fossil fuels will continue to increase, unless some major reforms or other changes take place.

Fig 3: Projections on global resource extraction 2005-2030; Business-as-usual scenario



Source: Sustainability Europe Research Institute (SERI), GLOBAL 2000, and Friends of the Earth Europe (2009). *Overconsumption? Our use of the World's Natural Resources*. Vienna & Brussels.

Moreover, Millennium Ecosystem Assessment (2005), Rockström et al (2009), UNEP (2012) and several other environmental analyses, show that these high and increasing levels of consumption have pervasive impacts on the world's aggregated natural capital and ecosystem functions. It is thus necessary to fundamentally address the issue and explore ways to live sustainably and make sustainable choices in consumption, and in other ways which may impact on the environment.

Measures: Sustainable lifestyles is about living well, within certain ecological limits. It pertains *inter alia* to our choice in consumption of various goods and services, including food, transport, energy use, housing etc. It is also closely related to our choice of work - type as well as total number of working hours – since individual income is to a large extent determining our level of consumption. It also pertains to our roles as members of a society, social relationships and actors in a political system. As voters or stakeholders in democratic political systems we have the opportunity as individuals to initiate or promote (economic, political or other) reforms which may facilitate systemic changes to our lifestyles.

Hence, attaining or promoting sustainable lifestyles may come via a range of policy instruments and (individual or collective) initiatives. For instance, progressive standards for product and production processes, clearly signaled to manufacturers in advance, are particularly effective as instruments for moving toward more-sustainable consumption. At the strategic political level, policies need to facilitate an “infrastructure of sustainability”, which includes access to effective and environmentally sustainable public transport, reuse and recycling facilities, and services for energy efficiency.

Fiscal and institutional frameworks must be designed to send consistent signals to businesses and consumers which promote sustainable consumption. Internalizing environmental costs of pollution and natural resource depletion in the market – via consumer prices of products and services – will have pervasive impacts on consumer behavior, investment decisions and lifestyles.

Challenges: Challenges to prevent current non-sustainable lifestyles, and find ways to reduce/reform consumption to promote sustainable choices cover a range of issues, and call for a multitude of

fundamental changes and measures. At the individual (consumer) perspective societies and markets must be reformed so as sustainable choices can be made. Currently that is not the case, regarding e.g. choice of energy type, mode of transport, food, fibers, fuel, housing etc. Sustainable choices are not always available or attainable due to distorted pricing/cost structures, physical and institutional lock-ins, lack of adequate information, limited access, unfavourable contracts etc. By ensuring clearer price signals, enhanced product labeling and consumer information, price reforms, access to sustainable choices, increased costs on polluting goods and services (and occasionally total bans on hazardous products) consumers/individuals can make sustainable choices. Fully implementing the polluter pays principle on environmentally harmful products and production processes would fundamentally reform price structures, favour sustainable choices and facilitate more sustainable lifestyles.

At the aggregated level facilitating sustainable lifestyles presupposes fundamental changes in parts of the prevailing trade regime, and the functioning of the global markets, by e.g. internalizing external environmental costs of harmful pollution from air and sea transport, raising taxes and tariffs on public bads (e.g. carbon emissions), and introducing subsidies or some other public promotion of environmentally benign goods and services. This applies for instance to environmentally sustainable sources of energy, modes of transport, housing types, foods and fibers.

Infrastructure for sustainable communities and sustainable cities

Promoting and attaining sustainable communities and sustainable cities – and in turn sustainable lifestyles - imply a range of challenges for reform in the physical infrastructure of societies. Essentially all countries are becoming more urban, and less rural: more people now live in cities than in rural areas. This urbanization trend is expected to continue, most notably in the emerging and developing world. Urbanization will provide opportunities for countries' development globally. However, all expanding urban areas are, and will be, dependent on functioning and increasingly productive ecosystems to provide for their needs. The production and consumption of goods and services in the cities' are all dependent safe supply of food, water, fuel and fiber, which are typically obtained from rural areas, domestically or from overseas. This is particularly important as many developing countries are transitioning from agriculture-led economies to manufactured products and service economies.

Trends regarding cities and urbanization show that in 2010 around 37% of the population in Sub-Saharan Africa lived in urban areas. It is expected to grow to 60% in 2050. Similarly, around 32% of the population in South-central Asia lives currently in urban areas. It is expected to grow to 57% in 2050. The trend is similar worldwide; perhaps the greatest urbanization will be experienced in South-eastern Asia, where the urban population will increase from 48% in 2010 to more than 70% in 2050 (UN-Habitat, 2011).

The rural-urban transition occurs with diverse growth patterns, and at different times across countries. Currently, Asia and Africa are less urbanized, but are expected to more urban than rural in 2023 and 2030, respectively. By 2050 their urban populations are expected to exceed 60%. Although research shows a positive link between urbanization and economic development, as well as technological innovation, increase material welfare and higher living-standards, enhanced

democratic accountability and women's empowerment, the expected urbanization process in the decades to come will put but extraordinary pressure on the world's ecosystems and natural resources. In Asia, urbanization – closely linked with rapid increase in industrial manufacturing - have been major factors behind the economic growth and poverty reduction in the region.

In order for the expected global urbanization process to be sustainable there is a need to develop and implement a range of sustainability measures and reforms: in particular sustainable energy solutions in urban housing, industries and other physical urban infrastructure, sustainable waste management, improved infrastructure for urban and urban-rural roads and transport, in particular enhanced public transport capacity and services. In addition, in order to promote sustainable urban futures there is a need to develop and implement sustainable water supply and management systems, sanitation as well as sustainable systems for supply and closed-loop management of food, fiber and fuel, to efficiently cater for the cities' development.

Challenges: The future needs of urban areas are not uniform. They have to be assessed independently and in accordance with the existing cities' and new settlements' bio-physical and socio-economic characteristics, needs and opportunities. However, cities of today will need to be designed and retrofitted to minimize waste, and optimize its use of energy, water and all other natural resources. Urban planning will increasingly have to internalize risks and uncertainties associated with e.g. climate change. Cities built or located in coastal locations are at risk from rising sea levels and will have to address climate-related extreme events such as storms and flash floods. Some is done today but much more is likely to be needed. For instance, energy infrastructure will have to be transformed to smarter, low-carbon energy systems. Transport will have to enhance traffic flows and -monitoring, planning and simulation, dematerialization (via e.g. e-commerce, videoconferencing, teleworking), more fuel- and material-efficient vehicles (plug-ins, hybrids and smart cars), private- and public-transport optimization, and smarter logistics solutions. Sustainable buildings will have to rely on smarter logistics, more energy and resource-efficient solutions, and dematerialization (e.g. via increased use of ICT) of building planning processes. Production and supply of power to and within cities will have to be based on smarter grids, more efficient generation of power, and more sustainable sources of energy (solar, wind, thermal etc.) and increased combination and integration of heating and power. Opportunities in waste management must be fully tapped via re-use, re-cycling and re-engineering where possible and feasible.

Addressing these challenges will most likely require a set of policy instruments, which allow for cost-effective implementation and flexibility (to prevent physical lock-ins). In addition to setting stricter standards, rules and norms for production, supply and management of energy, transport, buildings housing and infrastructure, water, fuel, food and fibers - to and within cities – there is a need for information, voluntary agreements, “contracts” between public-private spheres, optimized use of ICT solutions, but arguably most prominently stronger economic policy instruments; removing or gradual phasing out of harmful subsidies of natural resource-depleting and polluting activities (e.g. water, coal, gasoline), introduction of subsidies of environmentally benign activities in building and sustaining the cities, as well as taxes, fees, and levies, and review of tariffs on urban (public and private) goods and services, most importantly energy, transport, buildings housing and infrastructure, water, fuel, food and fibers. Reforming institutions and addressing the political economy issues of implementing these reforms will be critical.

6. Summary and Conclusions

The UN Conference on the Human Environment in Stockholm 1972 triggered a proliferation of environmental research, knowledge generation, increased awareness in society and among politicians, and policy reforms on environmental issues – problems as well as solutions. The Brundtland Commission introduced in *Our Common Future* (WCED, 1987) the concept of sustainable development, which inspired increased integration of social, economic and environmental issues, and reinforced the joint focus on environment and development. This was manifested in the UNCED-conference in Rio in 1992, which was decisive in the formulation and adoption of multi-lateral environmental agreements on biodiversity and climate change, and local work to promote sustainable development through Agenda 21. Since then, new financing, innovations and a set of new, mainly market-based economic instruments to manage the environment have been introduced. A government infrastructure of an environment ministry, an environmental protection agency (or equivalent), other associated environmental expert institutions, environmental policies and legislation has also been set up in most, if not all countries in the world.

Since UNCED in Rio, scientific advances have helped us understand more about the environmental challenges facing the world. Global environmental risks and boundaries have been identified (Rockström et al, 2009) as well as a set of “grand” challenges to attain global sustainability (Reid et al, 2010). Linked with the key environmental problems facing the earth (UNEP, 2011; 2012) - such as water scarcity, loss of biodiversity, deforestation and forest degradation, air, soil and water pollution, overfishing and other forms of natural resource depletion – the grand challenges proposed are to enhance *forecasting* and *observation* of the problems of global and regional environmental change, *confinement* and determining appropriate *responses* (institutional, economic and behavioural changes) and *innovations* which can facilitate and promote global sustainability. Research shows factual and likely risks of sudden abrupt changes of ecosystem functions which are triggered by unsustainable consumption and production. Current lifestyles increase the economic pressures on vulnerable ecosystems and scarce natural resources. Research shows that poverty in itself is a driving force of environmental degradation, but the dominant causal factors are increasing incomes and wealth levels in industrialized countries. Arguably, this call for fundamental and transformational changes of the way current and future populations consume and produce goods and services, and a reassessment and reformation of the values defining our lifestyles.

Regarding action, intensive work is being pursued in all sectors to find, market and scale up new sustainable technologies. Much has been achieved in increasing resource efficiency - in buildings, in transport, in energy supply, and in infrastructure, among others. Major economic, institutional and organizational innovations have been implemented to promote sustainable development, e.g. creation of environmental institutions, policies, legislation and cost-effective policy instruments. At the individual level measures are also undertaken. However, the speed of transition and innovation has been insufficient, and dependence on old non-sustainable (economic and physical) structures and patterns of production and consumption hold back necessary changes. Societies and individuals are subject to path-dependence in the ways work, production, consumption and mobility are organized and undertaken. Willingness to change at the individual level is hampered by (economic, institutional and political) systems, structures and lock-ins which sustain damaging pollution and excessive natural resource use. At the international level, individual country willingness to change

environmental performance is hampered by neighbouring countries or gridlock at the international *political* level. Hence, to attain a socially inclusive green economy requires *systemic* changes, at various scales, and a review and reform of the key sectors and policies which are determining the global development path. As has been pointed out (see e.g. Engfeldt, 2009), there is a need for bold decisions, and political leadership at the global level in order to solve the global environmental challenges. In particular, there is a need to take a larger and long-term responsibility in the task to ensure sustainable lifestyles, production and consumption and innovations. Here, the responsibility is largest among the industrialized developed countries, which have contributed historically, and at present, the most to create the world's major environmental challenges. However, the picture is quickly changing so the task is shared across all countries with a differentiated responsibility and burden of action.

Although the world is currently facing major environmental pressures, risks and uncertainties, there are also, still, large untapped opportunities to steer consumption and production patterns and lifestyles towards sustainability. Arguably most promising are the rapid changes and introduction of new technologies and innovations, behavioural changes in consumption in segments of various markets (e.g. food, tourism, buildings, transport), increased efficiencies and smarter low-carbon production patterns and technologies. Introducing *green economy* as a concept and pathway to sustainable development offers indeed new opportunities by its sharp focus on putting a price on pollution and unsustainable resource depletion, and active use of economic instruments (fees, taxes, levies, subsidies, and removal of subsidies) to raise government revenues *and* attain environmental benefits. It strongly suggests an increased responsibility among ministries of finance and the business sector to be part of the solution, and a provision for use cost-effective incentives to trigger the much needed change. However, using economic instruments is not new, especially not among OECD countries; current achievements have been useful and necessary, but insufficient to initiate any major change towards sustainability of production and consumption patterns. Focus on the scale effect – the total pressure on the environment - is essential. Hence, increased use of economic instruments may be useful but constitute only a subset of all the measures need to attain sustainable development. Increased attention must also be paid at distributional aspects, stakeholder involvement and the social dimensions in the reform of environmental and economic policies towards a green economy.

As science points out, there are at least three critical environmental sustainability dynamics at play: climate change, degradation of ecosystems and increasing scarcity of several of the world's key natural resources. The issues are interlinked as well as the solutions. In addressing these issues and their links with social and economic development, there are urgent needs for new technologies, and new and better policies, implementation of these policies, and an increased use of information, voluntary agreements, and economic instruments. These changes are necessary but insufficient. What are needed are new resilient lifestyles and societies, and clean and green patterns of production and consumption. In order to achieve this there is evidence of a need for a *new understanding, new ethics and a redefinition of well-being* as means to adapt and transform human activities in line with the bio-physical conditions and restrictions set on the planet. For this to happen there is arguably a need for a re-definition of the current development paradigm, and changed norms in the human-environment relationship.

Issues to address within the scientific community as well as in the political sphere, in business and civil society are if, and how, sustainable production, innovations and lifestyles can be transformed and aligned with the biogeochemical boundaries set by the world's ecosystems? How can societies and the global community be enabled to meet the risks of climate change, and meet future needs for food, water, energy, health and human security without putting the world's ecosystems at risk? What are the opportunities and key constraints to attain the dual objective of enhancing human social and economic development *and* ensuring the world's natural capital and ecosystem services? Assuming there are unavoidable trade-offs, which are they and how can they be reconciled in the best manner, and can how production and consumption patterns be reformed, and innovations be developed, to help minimize these trade-offs?

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