

# **The Winners of the Blue Planet Prize**

**2000**



2000

## Blue Planet Prize

**Dr. Theo Colborn  
(U.S.A.)**

Senior Scientist and Director, Wildlife and Contaminants Program, World Wildlife Fund

**Dr. Karl-Henrik Robert  
(Sweden)**

Chairman of The Natural Step (NGO)



At the 2000 Blue Planet Prize Awards Ceremony, the opening slides highlighted the tones generated by the gene sequences of living things. Tones found in the heartbeats and voices of all living creatures and in the sounds of nature inspires our original score "Resonance," and the image sequences.



His Imperial Highness Prince Akishino congratulates the laureates.



Hiromichi Seya, chairman of the Foundation, delivers the opening address.



The prizewinners receive their trophies and certificates of merit from Chairman Seya.  
Upper: Dr. Theo Colborn  
Lower: Dr. Karl-Henrik Robert



Thomas S. Foley, Ambassador of the United States to Japan (left), and Krister Kumlin, Ambassador of Sweden to Japan (right), congratulate the laureates.



Prior to the awards ceremony, the award recipients meet the press. From right: Dr. Robert; Dr. Colborn; Chairman Seya; and Kimihiko Sato, senior executive director of the Foundation.



The Blue Planet Prize Commemorative Lectures.

## Profile

# Dr. Theo Colborn

Senior Scientist and Director, Wildlife and Contaminants Program, World Wildlife Fund

### Education and Academic and Professional Activities

- 1927 Born in March in the United States.
- 1947 B.Sc., Pharmacy, Rutgers University.
- 1981 M.Sc., Fresh Water Ecology, Western State College of Colorado.
- 1985 Ph.D., Zoology, University of Wisconsin-Madison.
- 1985-1987 Congressional Fellow, Office of Technology Assessment.
- 1988-1993 Researcher, World Wildlife Fund.
- 1990 Fellowship, W. Alton Jones Foundation.
- 1991 National Water Alliance Award.
- 1993 Pew Scholars Award.
- 1993— Senior Scientist and Director, Wildlife and Contaminants Program, World Wildlife Fund.
- 1994 National Conservation Achievement Award.
- 1997 United Nations Environment Programme, Women Leadership in the Environmental Award.
- 1997 State of the World Forum, Mikhail Gorbachev "Change Makers Award."
- 1999 Norwegian International "Rachel Carson Prize."

Dr. Colborn investigated declining populations and abnormalities in development, reproduction, behavior and immune systems and other phenomena that had caused concern about wildlife in North America's Great Lakes area in relation to cancer-causing agents. However, she was unable to find a correlation between these data and cancer. At that point, she hypothesized that these phenomena might be related to the disruption of endocrine systems by synthetic chemicals. As she continued to analyze mountains of studies, she confirmed this hypothesis, revealing that certain chemicals being released into the environment were being concentrated via the food chain and disrupting the endocrine systems of wildlife and humans.

In 1991, she invited 21 expert researchers from various disciplines to a conference in Wisconsin State in the United States to scientifically examine the effects of endocrine disruptors on the reproductive, developmental and physiological functions of wildlife and humans. The "Wingspread Consensus Statement" announced by the conference participants advised that the endocrine disruptor chemicals that threatened wildlife were endangering the future survival of humankind, and they informed the world that this was a problem that had to be dealt with expeditiously.

In 1996, Dr. Colborn aroused the world's attention with the publication of *Our Stolen Future* a book she co-authored. It explains in simple terms how persistent synthetic chemicals

are collected in the body, how they cause abnormalities by disrupting the functions of the endocrine system and how they adversely affect the next generation.

Through the submission of her information on these problems, Dr. Colborn prompted the United Nations, the OECD countries, the North American and European countries and Japan to undertake full-fledged studies, research and countermeasures to deal with the problem.

## Say 'No' to Toxic Hitch-hikers

Dr. Theo Colborn

June 2001

Scientists, industrialists and governments are seemingly locked in a perpetual battle over the issue of climate change. As the parties come closer to agreement on the need to address the problem, cost-benefit analyses will drive political decisions on how and what should be done next. It is time that a new set of benefits that have heretofore received little attention should be included in the strategies for reversing the warming trend. Global climate change has clearly been identified as the result of atmospheric accumulation of greenhouse gases that include carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), sulfur hexafluoride (SF<sub>6</sub>) and a number of the ozone-depleting chlorofluorocarbons. The largest source of these gases that trap and hold heat in the earth's atmosphere is combustion. Combustion of fossil fuels also produces dangerous compounds that pose a threat to our children before they are born, and to their children and grandchildren. These compounds include some well-publicized, persistent, organochlorine chemicals such as dioxins, also called TCDDs, furans, hexachlorobenzene (HCB), polychlorinated biphenyls (PCBs) and trace metals like mercury and cadmium. The amounts of these toxic hitch-hikers might seem insignificant compared to the tons of greenhouse gases that are released. But their impact on human and wildlife health and the global economy is significant. Unfortunately, their toxicity is so great that only the newest, most sensitive instrumentation can measure the concentrations at which they can injure living organisms. Their invisibility, similar to the nature of their toxicity, is so insidious that when environmentalists and climatologists began to focus on the problem of global warming, their role was not yet understood.

Dioxins, furans, HCB and PCBs are associated with serious widespread human and wildlife health problems. Human prenatal exposure to PCBs, dioxins and mercury has been significantly correlated with impaired intelligence, behavior, immune competency, reproductive success and metabolism. Wildlife exposure to these same chemicals, especially in aquatic systems where the chemicals readily biomagnify in the food web, has led to severe reproductive problems in a number of species with occasional regional extirpation of some populations. The economic benefits from lowering emissions of these compounds could be astronomical. Reductions would improve the quality of life and assure the integrity and perpetuation of all species, including humans.

The Great Lakes basin of the United States and Canada offers an example of the dam-

age these toxic substances can cause. In the late 1890s and early 1900s, the chlor-alkali industry started to produce free chlorine (a chemical that has improved the general health of the world) at a number of locations on the shores of the Great Lakes. Industrialists had no idea that they were inadvertently producing dioxin and causing widespread contamination. By the 1930s and 1940s, top predator fishes, herring and lake trout, began to disappear in the Great Lakes, resulting in the declines of several huge commercial fisheries. It took until the 1990s for scientists at the University of Wisconsin, Madison, to discover that very low concentrations of dioxins in lake trout eggs injure embryos so that they are unable to reach maturity. About the same time, EPA scientists doing core drills in Lakes Michigan and Ontario discovered that dioxin concentrations in the lakes were high enough in the 1930s and 1940s to prevent these top predator fish in the lakes from reproducing. This raises questions about whether the loss of some of the major ocean fisheries in the world might not have been in part the result of the global dispersal of dioxins, furans, PCBs and similar organochlorine chemicals. Black-footed albatrosses that feed only on the surface of the North Pacific Ocean and nest on Midway Island are already carrying elevated levels of furans, dioxins and PCBs near or above concentrations at which aquatic birds are being affected in the more highly contaminated areas of the Great Lakes.

It has taken the regulatory community years to reach the conclusion that dioxin is a human carcinogen. Reducing cancer associated with exposure from stack emissions is a hidden benefit. But cancer is only one of the many impacts these chemicals can have on animals and humans. The greenhouse gases' co-contaminants are also endocrine disruptors, chemicals that look like or interfere with the hormones that control the development of an individual from conception to birth. Their effects are insidious and can undermine an individual's ability to reach his or her fullest potential. Biologists have learned how devastating impacts like this can be on a population from their experience working in the field with wildlife. They warn that endocrine disruptors can lead to the loss of wildlife populations without society knowing what is happening. They also agree that endocrine disruptors can change the character of human societies. These chemicals can interfere with the developing brain and nervous system, and humankind, again, could miss what is happening. As a matter of fact, cancer is essentially a rare event compared with the impact of these chemicals on populations of wildlife and humans. Cancer has never led to the extirpation of a wildlife population, but prenatal damage as a result of exposure to PCBs, dioxins and furans has caused populations of fish and birds to decline dramatically or disappear.

Among humans, for those individuals who survive birth, insidious health effects such as susceptibility to disease, autoimmune problems, learning problems, early or delayed puberty, abnormal urogenital development, reduced sperm count and fertility problems may not be terminal or lethal, but certainly impair quality of life. And their social costs can be significant.

For example, prenatal exposure to background or ambient levels of PCBs can interfere with the development of the brain. This is reflected in reduced Intelligence Quotient (IQ) scores and disturbing behavioral changes. Children exposed prenatally are hyper-reactive, cry a lot, are fearful and do not settle down well; they do not habituate well to strange or

unpleasant surroundings. They have difficulty reading and processing information, and can be as much as two years behind in school by the time they reach the 6th grade. Their odds of becoming law-abiding, tax-paying adults are reduced as a result of their prenatal exposure to PCBs, dioxins and furans. Their lifetime earning ability is jeopardized.

PCBs and HCB were not considered harmful when they were first produced on a large scale. And dioxins, furans and mercury, as by-products of combustion, were never intentionally produced or released. The impact of these chemicals on behavior and function is not easily identifiable at the individual level. It has taken expensive, long-term epidemiological studies, some as long as a generation (20 years or more), to determine the damage from exposure to these greenhouse gas hitch-hikers in humans. It is clear what society has to gain by removing them from the environment. And as analytical chemical protocols improve, more hitch-hikers may be discovered spewing into the air along with the greenhouse gases that have been overlooked thus far. There could be a lot more to gain than meets the eye. It is time to tally up the benefits and take action.

## Lecture

# Inner Space Research: Assuring the Integrity of Future Generations

**Dr. Theo Colborn**

I want to thank the Asahi Glass Foundation for providing me the opportunity to come to Japan to speak to you. It is with great humility that I stand here, because the research behind my message was not done by me, but by vast numbers of scientists around the world. It is the cumulative result of their research that the Blue Planet Prize is recognizing. I only come to this podium with my interpretation of their story.

I am going to share with you some of their remarkable findings that have led to concern on the part of many scientific and public health professionals about the manner in which governments have managed the man-made chemicals that you encounter in your daily lives. Second, I am going to provide several examples of what has prompted this concern. Some of you may feel a little uncomfortable with what I am going to say. That is because I am going to describe some disturbing health problems that are not generally discussed in front of large audiences—a fact that may be contributing to the health authorities' difficulty in dealing with the problem—because not enough people are aware of the problems. And, I will close with some options for addressing the problem—for it is not just governments and corporations that need to address this problem. There are things that we can do as individuals as well.

### Inner Space

Today, I want to take you on a journey into space. Not to outer space to explore the surface of Mars, but to inner space where every one of you has been already. To the womb—where, from the moment your father's sperm entered your mother's egg, until you were born, you spent approximately 266 days.

In the inner space of your mother's womb, with unbelievable precision, your cells replicated, moved about, and formed buds that grew into limbs and brains and sensory and reproductive organs, contributing to the most miraculous phenomenon on Earth. You. From the moment of your conception, your development was orchestrated solely by chemical messengers called hormones. Constantly shifting blends of hormones told your cells when to divide and where to move as your endocrine system supervised your construction. Only within the past decade have scientists been able to measure the infinitesimally small concentrations of hormones that engineered you. From recent laboratory studies we now know that your developing systems were so fine-tuned that they depended on shifts in hormones in concentrations as little as a tenth of a trillionth of a gram when you were in your mother's womb environment. That is as inconspicuous as one second in 3,169 centuries.

The technology that provided these insights on inner space is dragging years behind the

outer-space and cyber-space technology that have contributed to the 500 or more chemicals that every one of you is carrying in your body today—chemicals that no one was exposed to before the 1920s. There is now undeniable evidence that a pregnant woman shares some of these chemicals with her baby in her womb—and at even higher concentrations with her baby when she breast feeds—chemicals capable of interfering with the natural hormones that tell the baby how to develop. Some chemicals can interfere not only with the actual physical structure of the systems, but with the imprinting of these systems as well—such as improperly programming the brain so that an individual does not respond to the hormone messengers that ordinarily would control how he or she functions later in life.

Without realizing that man-made chemicals could pierce the placental and brain barriers and interfere with fetal development, we have in the 20th century released large volumes of chemicals into commerce and the environment that can mimic or interfere with natural hormones. They are often found at 100- to a 1,000-times higher concentrations in human tissue than the natural hormones themselves—in wildlife tissue, even higher. Although they may be weaker than the natural hormones, at concentrations that high, they can out-compete or perturb natural hormone signals in numerous ways.

These chemicals do not damage chromosomes and thus have eluded us. Much of traditional toxicology is directed at detecting damage to chromosomes. Instead, these chemicals interfere with the ability of genes to modulate the production and action of signaling chemicals such as hormones—so that the genes cannot express what they have evolved to do. In so doing, unfortunately, there are infinite ways that disrupted gene expression can interfere with the development and function of an individual. In terms of quality of life, the costs can be high.

## **Exposure**

You, your children and your grandchildren are all exposed to these kinds of chemicals. You are not exposed to one chemical at a time, but to a complex mixture of chemicals that changes hour by hour, depending on where you are and the environment you are in. You cannot escape exposure in your homes, offices, schools, hotels, meeting rooms, gymnasiums, automobiles, airplanes and the outdoors.

Many of these chemicals build up in the body and remain in human tissue from one generation to the next. Others do not build up in tissue, but are constantly present in your daily lives. They are in the common, everyday products people have become dependent upon, such as plastic products, including toys, food containers, medical equipment, automobiles, TVs, cell phones and computers. They are used to line food and drink cans, and to make compact discs, sporting equipment, high-impact parts for vehicles and vast amounts of construction material.

They range from industrial chemicals, to pesticides, to perfumes and cosmetics. They are found in fast foods, deep ocean fish and even the most rigid, organic, vegetarian diet.

Let me reinforce what I have said so far: wildlife tissue from the Arctic to the Antarctic contains chemicals that can undermine the development of the brain, and intelligence and behavior, and the endocrine, immune, and reproductive systems—vital systems that assure the perpetuity of species.

A growing collection of wildlife, human and laboratory studies reveals that some of

these chemicals can affect our children's ability to learn, to socially integrate, to fend off disease and to reproduce. Unfortunately, invisible, delayed effects such as these are difficult to link with exposure to a specific chemical—especially when the target animal is the offspring, not the initially exposed individual—and the effects are manifested in the next generation.

A group of international experts unanimously agreed that chemicals of this nature can change the *character* of human societies or destabilize wildlife populations without society realizing what is happening. The group called for using precaution—to reduce exposure and to practice prevention—rather than continuing to try to develop cures for conditions that cannot be repaired.

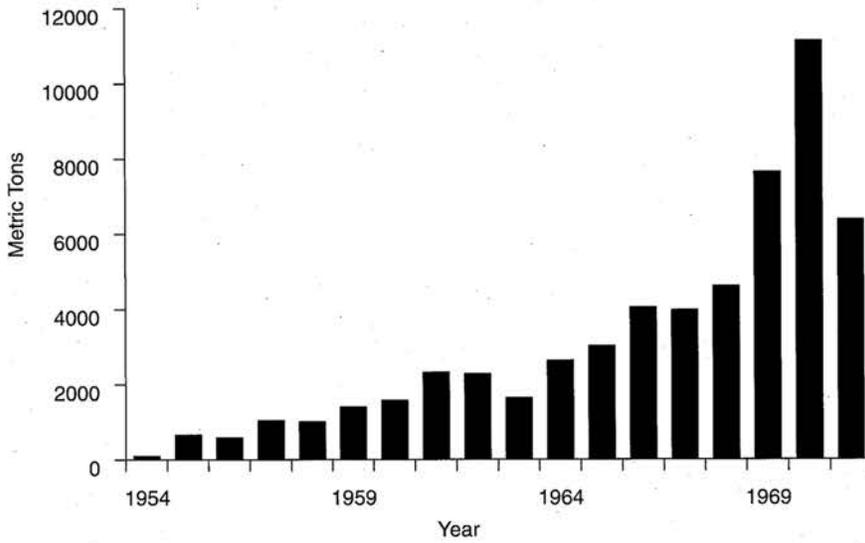
### **Neurodevelopmental Impairment**

The concept of endocrine disruption emerged from a 1988 analysis of the health status of wildlife around the North American Great Lakes, the largest body of fresh water in the world. Where the adult animals, if present, looked fine—but their offspring, if they had any, rarely survived to adulthood—and if they did survive to adulthood, they rarely could reproduce.

In response to concerns like these about the health of wildlife that consumed fish from the Great Lakes, a human epidemiological study was started in 1979, comparing children born of women who ate Great Lakes fish and those who did not eat the fish. The results of that early study combined with a series of newer studies contributed in part to the issuing of the consensus statement I just mentioned. The first study commenced 20 years ago; others have followed.

These studies have confirmed that prenatal exposure to a group of widely dispersed, persistent industrial chemicals, such as PCBs, dioxins and similar chlorinated compounds, can undermine neuromuscular and neurological development that trained technicians can measure at birth in humans. The infants' parents or family physician would not be able to detect these problems.

PCBs are oily, very stable, and thus persistent liquids that were used as fire retardants in transformers, capacitors, and other electrical and construction products. They were produced under the name Kanechlor in Japan. Their production was banned in Japan in 1972, seven years before they were banned in the U.S. where they are still widely used in closed systems at low concentrations. They will be in the environment for hundreds of years.



**Figure 1.** Annual Kanechlor production in Japan from 1954–1971. (Source: Loganathan et al. Environmental Pollution, 1993)

Two Great Lakes studies confirm that as the prenatally-exposed children mature, they exhibit short-term memory problems and are difficult to calm down in unpleasant situations. In the earliest study, the more highly exposed children’s average reduction in IQ was 6 points at age 11, with some of the children more than two years behind in reading and school performance.

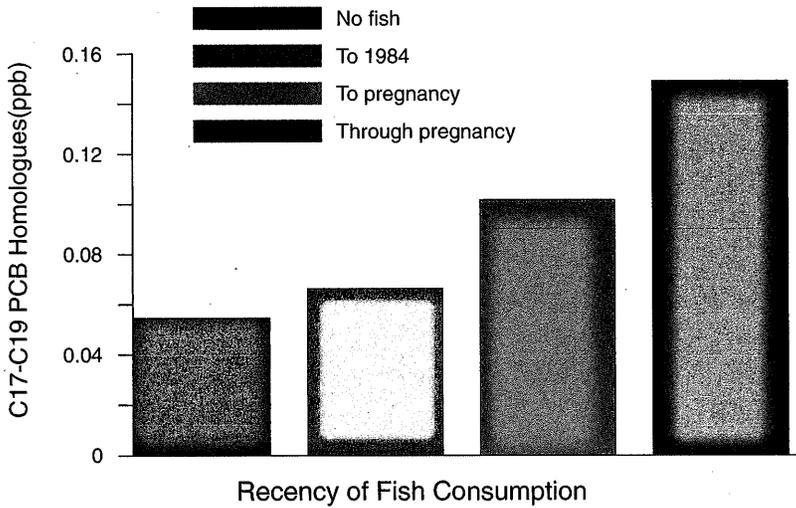
**Table 1. Lake Michigan Findings**

<p><b>Mothers' Fish Consumption</b> Fein, et al., 1984</p> <hr/> <p><b>Higher PCB Cord Serum Levels</b> Jacobson and Jacobson, 1993</p>  <p>Jacobson and Jacobson, 1996</p>	<p><b>At Birth:</b> Poorer neuromuscular maturity Higher PCB cord serum levels</p> <hr/> <p><b>At Age 4:</b> Poorer short-term memory Lower cognitive processing speed Auditory verbal deficit Quantitative memory deficit Lower visual discrimination memory</p> <p><b>At Age 11:</b> 6.2-point deficit in IQ 6 to 12 months behind in word and reading comprehension</p>
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Another independent study using only healthy mothers and infants 12 years later followed the protocols in the first study, but also utilized more psychological tests. These children also had the same memory problems and difficulty with processing information relative to the concentrations of PCBs they were exposed to in the womb.

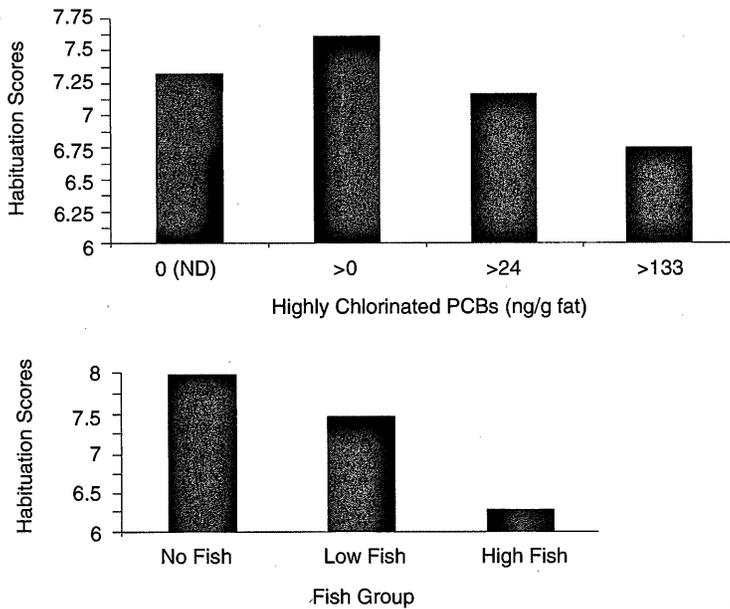
Using a new psychological test to determine temperament, the second team also found that the affected children cried more, laughed less, expressed more fear and did not habituate well to changes in their environment.

There was a marked increase in the mothers' PCB blood levels if they ate Great Lakes fish prior to their pregnancy and throughout their pregnancy compared with those mothers who stopped eating GL fish when they found out they were pregnant. There was an even greater reduction in the mother's blood PCBs if they stopped eating GL fish in 1984 when the first fish advisories were released. Even with convincing research results such as this, there are those in governing positions who do not want to release fish advisories because they might discourage tourism. They argue that it will have a negative impact on the recreation industry around the Lakes.



**Figure 2.** C17-C19 PCB congeners in controls, women who stopped consuming fish in 1984, women who stopped consuming fish upon learning of their pregnancy, and women who ate fish throughout their pregnancy. (Source: Stewart et al. Environmental Research, 1999)

Note the relationship between the PCB concentrations in the mothers during gestation and their children's ability to habituate to changes in their environment. Their habituation scores decreased in a dose-response manner as the mothers' blood levels of the more persistent highly chlorinated PCBs increased.



**Figure 3.** Habituation (48 hrs. postnatal). (Source: Stewart et al., 1999. Neurotoxicology and Teratology)

The average PCB level in all of us in this room today is undoubtedly within the range at which the affected children in the studies were exposed prenatally. Fish are not the only source of PCBs. Society is going to have to decide if it wants to gamble with exposure odds like this—and risk the loss of our best and brightest—our future scientists, educators and world leaders. It will also have to decide whether it wants to reduce the odds that children will end up in special education classes and under the surveillance of social service agencies.

An entirely different study that also looked at healthy mothers and infants from both the urban and suburban Netherlands did not include the extensive psychological testing used in the Great Lakes study, but it did detect neuromuscular delays, measured as hypotonia and abnormal reflex responses, which is similar to the results in the other mother-infant studies. In this study, the mothers were not selected because they were fish eaters.

**Table 2. Netherlands Studies**

n=418*	hypotonia		43% muscle tone	↓	22% reflex	↓
n=207**	CD4 T-cell receptors (birth)	↑	CD4 and CD8 T-cells (18 mos.)	↑	Monocytes and granulocytes	↓
n=105***	free thyroxine and total thyroxine	↓				

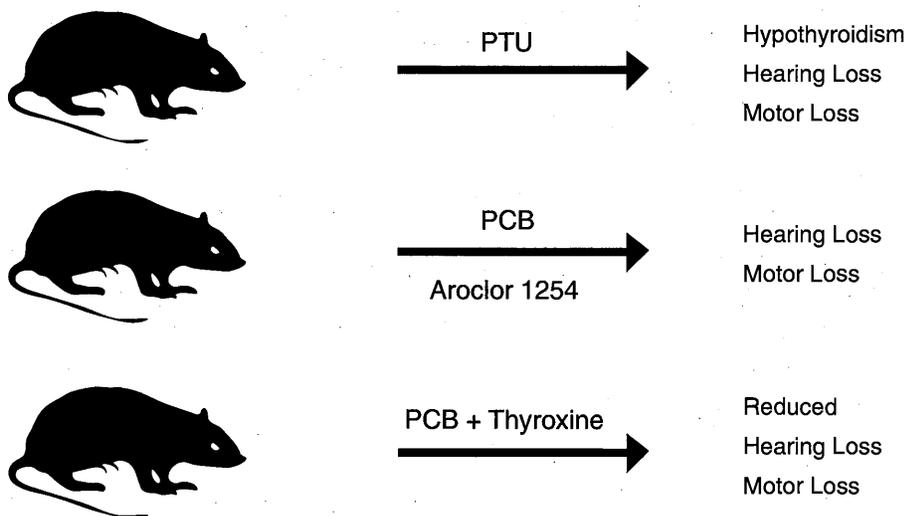
\*Sauer *et al.* 1995

\*\*Weisglas-Kuperus *et al.* 1995

\*\*\*Koopman-Esseboom *et al.* 1994

The researchers also found an association with increased levels of PCBs and dioxin in the mothers' blood during gestation, with increased changes in the children's immune systems and reduced thyroid hormone levels.

It has been known for over a century that thyroid hormones are critical for proper brain development and intelligence. Scientists have discovered innumerable ways in which PCBs disturb the thyroid system. In one series of laboratory studies, it was demonstrated that prenatal exposure to PCBs causes loss of motor coordination and loss of hearing for low and intermediate frequency sounds in rat pups. Loss of auditory discrimination such as this has been linked to difficulty with phonics, reading, learning and ultimately intellectual development. Like the laboratory rats, the children in the PCB studies I mentioned earlier had difficulty with what psychologists call audio-visual discrimination—which they will tell you could have led to the children's reading and scholastic problems.



**Figure 4.** U.S. Environmental Protection Agency Studies. (Sources: Goldey et al., 1995; Herr et al., 1996; Goldey and Crofton, 1998)

A medical doctor and thyroid specialist on my team recently published a literature review on the effects of environmental chemicals on the thyroid system. We were surprised at the length of her list of environmental chemicals that affect the thyroid. Although this information is published in prestigious scientific journals, governments do not regulate chemicals based on what is found in the literature. Because of the increasing number of new chemicals introduced into commerce each year, governments are forced to depend on the information industry provides them about the safety of their products. To date, industry has no standardized protocols to test chemicals for these effects.

### Population-Level Impairment

The second set of studies that I want to tell you about also comes from the Great Lakes region. In this study, researchers administered cutting-edge, low-doses of dioxin to rats and fish.

They found that the very low doses, orders of magnitude lower than anyone had ever used before, could have significant effects on male sexual development in rats—and survival of hatching embryos in fish. This data has never gotten the recognition it deserves by fisheries managers or risk assessors. The battle over the safety of dioxin continues to focus on its carcinogenic effects. Beware, because cancer in the case of dioxin is like a red herring, detracting attention from what could be, its far more prevalent, insidious, developmental effects.

Based on this data, later in 1995, organochlorine analyses of core drills of Lake Michigan sediments revealed that there was sufficient dioxin in the Great Lakes as early as the 1940s to prevent lake trout and other top predator species in Lake Michigan from maturing. Further testing of core drills in Lake Ontario provided the same evidence. Historically, these findings coincide with the first large-scale production of free chlorine using the chlor-alkali process along the shores of the lakes. The fish disappeared from the Lakes about the same time

as giant industrial and pharmaceutical industries adopted catalytic chlorine chemistry technology. The dioxin-exposed fish eggs hatched, but they suffered from edema and hemorrhages and did not survive through swim up.

Today, Canada and the U.S. combined, spend approximately \$50 million a year raising and stocking the lakes with top predator fish because most populations of top predator fish are still having trouble reproducing there. Fisheries managers still insist that over-fishing, habitat destruction, and the lamprey eel caused the crash of the top predator fish in the Lakes in the 1950s. Managers are reluctant to get involved with the issues of contamination and their effects on the development and reproductive success of fishes. This holds true with managers not only of freshwater species but marine species as well.

Seventy percent of the world's commercial marine fish stocks are threatened with extinction. No one can deny that over-exploitation of the fisheries resource is a serious problem, but with the evidence available today, it is time to add contaminants considerations to the management of all free-ranging species.

We must take precautionary steps to reduce the release of dioxin and other persistent organic chemicals, called POPs, that eventually move to the seas and oceans and to the animals that live there.

Let me recapitulate for a minute: there is clear evidence that, in less than a century, humankind has changed the chemistry of the Earth with compounds that were considered safe because they did not cause cancer or other very obvious toxic effects. And over the past decade, we have begun to recognize the fact that indeed, some of these chemicals do enter the womb environment and cause irreversible changes—changes that are invisible and sometimes not expressed until an individual reaches adulthood—but changes that ultimately undermine the individual's potential in endless ways. Many of the chemicals of concern are either residuals from past use, or current-use pesticides and industrial chemicals upon which we have been told repeatedly that our survival and economy are based. Yet it appears that some of these products may be costing a lot more than their market price when their generational effects are taken into consideration.

### **Individual-Level Impairment**

I want to tell you about one more condition that *is* visible at birth as the result of something that goes wrong during sexual differentiation in the womb during a limited period of time. The condition is called hypospadias, one of the most common birth defects in the U.S. today, although it is not talked about much. Hypospadias is a condition where the urethra does not open at the end of the male external organ. In mild cases, the opening is near the head or the end of the organ. In the more severe cases, the opening is located anywhere along the shaft or even in the scrotum. Hypospadias has only one treatment. Surgery. The closer the urethral opening is to the body, the more difficult the surgery. The difficult cases cannot always be corrected. Embryologists know that this abnormality starts somewhere between day 56 and 84 in the womb—when the urethra and male organ begin to lengthen and enlarge together.

A very special male steroid hormone is required for this remarkable process to take place, and scientists have now discovered a number of chemicals in various ways can interfere

with the production and activity of this hormone.

Hypospadias doubled between 1970 and 1993 in the U.S. and now occurs in approximately 1 in 125 boys. The more severe cases appear to be increasing more rapidly. Boys born with hypospadias have a significantly greater risk in adulthood of developing testicular cancer and reproductive problems. It behooves us to try to understand what a condition like this can do to the quality of life of these young men as they mature.

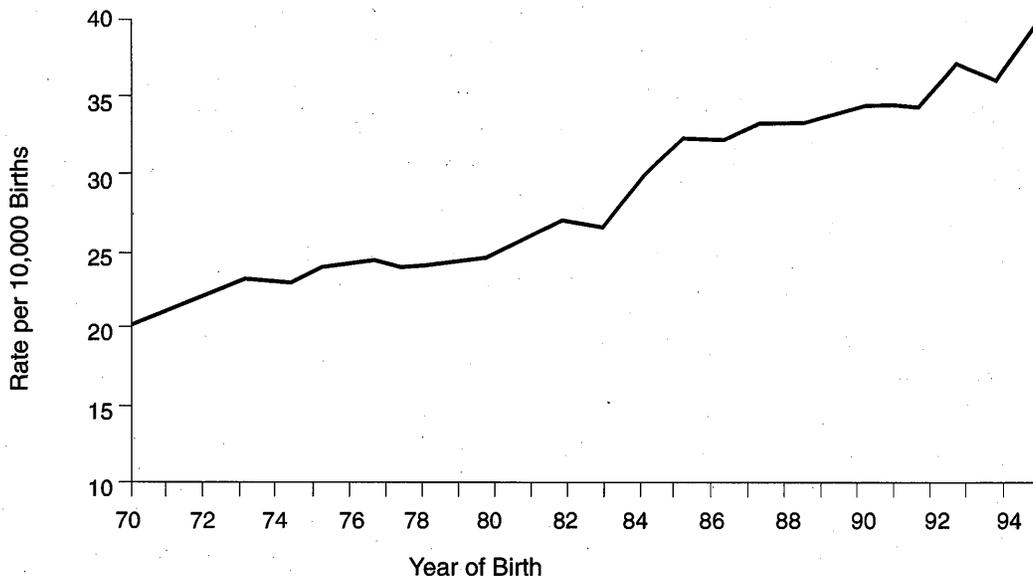


Figure 5. Hypospadias rates: 1970–1993. (Source: Paulozzi et al., 1997)

Just think about this—if wildlife biologists had not discovered that a large number of alligators from Florida’s Lake Apopka had small phalluses, or external male organs, and were barely capable of reproducing, scientists would probably never have discovered that there are chemicals in the environment that can interfere with male hormones, the testosterone. No one knew that there were any environmental anti-testosterones until six years ago.

When the wildlife biologists showed some alert Environmental Protection Agency (EPA) toxicologists pictures of their alligators’ unusual external male organs, the EPA men asked immediately what the alligators could be exposed to. The biologists thought that perhaps DDE, the breakdown product of DDT, might be involved. Much to everyone’s surprise, it was. Not only do the male offspring of rats fed DDE suffer from hypospadias, they also suffer from undescended testicles and other disturbing developmental problems. I will make a bet with anyone in this room that at least 95% of you will have measurable DDE in your bodies. To be sure, the women who have breastfed several babies will have the lowest DDE concentrations because they will have unknowingly released an appreciable part of their body burden into

their babies while nursing. This is something that women should not have to accept or worry about.

Thanks to some forlorn alligators in Florida's swamps, we now know that some pesticides used on fruits and vegetables, some plastic components and DDE could cause hypospadias in humans if the timing of exposure is correct. Amazingly, DDE is one-tenth as potent as flutamide, a drug used to chemically castrate men with prostate cancer. This is the son of a DDE-fed rat. This is the son of a fungicide-fed rat. The fungicide is vinclozolin.

Let me repeat here, that there are no standardized protocols to screen and test chemicals for hypospadias or any of their other hormone-disrupting effects, including intellectual and behavioral impairment that I mentioned earlier. Consequently, there is no way governments and corporations can assure that any product in use today is safe—not until these tests become available.

Developing the tests is going to require an international effort because so many chemicals are now an integral part of the global economy and commerce. And persistent chemicals like PCBs and DDT flow on air and water and ocean currents as well as in commerce, and are accumulating in animal and human tissue thousands of miles from where they were used.

### **Entering the Inner-Space Age**

In 1996, it looked like the U.S. was going to take the lead on this issue. The U.S. Congress wrote into the reauthorization of both the Safe Drinking Water Act and the Food Quality Protection Act—the U.S. pesticide law—that EPA must come up with a set of protocols to test chemicals for their endocrine disrupting effects and get a program in place by 2000. There was great expectation at that time that the U.S. government would take the lead and establish such a set of tests that could be used globally. Unfortunately, here we are almost through the year 2000 and not one test has been standardized or validated yet. It is very apparent that if we wait for the U.S. government or any other government to move on this, we will continue to use our children as substitute laboratory subjects—and wildlife species will continue to slowly disappear.

Are we going to wait until every child is affected? Are we going to continue to gamble that our sons will *not* be hypospadiacs?

The individual costs and *societal* costs are just too high not to change the system. We must move from complacency and from assuming that governments will provide protection from chemicals of this nature. We must act as soon as possible. Manufacturers of products that enter our homes want a set of tests to assure that their products are not posing risks to us and future generations.

It is obvious. We need a new inner space effort that is funded as generously as previous outer space efforts. It must be an international, independent research effort that moves ahead rapidly to undo what has evolved as the result of the chemical technology that grew out of World War II. Governments, by nature, will not move forward fast enough. Consequently, industry is going to have to take the lead and come forth with the money. With sufficient funding and shared goals, industry could give the world, in a very short time, the rudimentary screens and assays for detecting chemicals that are endocrine disruptors. As the new inner

space program probes deeper into the mysteries of development, more and better assays will be proposed. In light of what already has been discovered in the past 10 years and the complexity of the endocrine system, it is apparent that the commitment to this research must be long term.

There is no doubt in my mind that industry can do this. We just saw what industry can do if it wants to. In less than three years, it spent billions of dollars preventing a Y2K crisis, and at the same time it helped the economy. The effort I am calling for would require far less of industry's time and investment. It would also create jobs, and it would assure a healthier, more productive society. I envision a three-branched infrastructure, with industry on one branch providing the money. The second branch would handle the money and provide a buffer between industry and the third branch, comprised of scientific experts.

The process of framing the research, conducting the research, evaluating the results and sharing the information with the public must be beyond reproach. The credibility of the effort will hinge on keeping industry and government and other funders from influencing how the research is designed and the results reported.

This is important because the public has lost faith in industry's research when it comes to health issues. Many business people agree that even if industry were to do good science, the public would not believe it. It is to industry's advantage to have the research done independently. In no way should the shame of "cigarette science" taint this effort.

I have learned from previous speaking engagements that many of you are wondering how you can become involved at the personal level. How can you protect yourselves and your families?

First of all, you can become more knowledgeable about the products you bring into your home. Ask for more information on the labels of the products you purchase. Call and write manufacturers and tell them you want assurance that there are no endocrine disruptors in their products. Tell them to support the international research effort.

Seek safe alternatives for the pesticides you use in your homes, gardens and lawns. Purchase organically grown food whenever you can. In so doing, you not only reduce your exposure but that of thousands of farm workers. And by reducing the use of pesticides in the fields, you are also protecting the beneficial attributes of natural systems that are essential for sustained agriculture.

Never heat something in plastic in your microwave even if the container says "microwave safe." That statement is based on whether the chemicals that leak from plastic containers cause cancer, not whether they have endocrine system effects. Wash children's hands frequently.

At the community level, get involved in neighborhood groups to discourage the use of pesticides in your area, and urge your schools to join a nationwide campaign to remove pesticides from schools and playgrounds and gymnasiums. On a broader scale, perhaps through a breast cancer or prostate cancer action group, insist that they support research that is based on prevention not just treating symptoms, because, as I mentioned with hypospadias, there is growing evidence that prenatal exposure to endocrine disruptors can lead to sex-organ cancers later in life. Few research dollars are directed toward the impact of prenatal exposure to syn-

thetic chemicals on cancer incidence. Yet, a great deal of evidence has accumulated over the past 10 years suggesting that this could be a factor in secondary sex-organ cancers.

At the international level, Japan has a critical role to play in the international treaty negotiations on Persistent Organic Pollutants (POPs), which will reach closure in December. You need to urge your government to support elimination of the 12 targeted POPs, to incorporate precaution as a guiding principle of the treaty, and commit sufficient technical and financial assistance to ensure that all nations can participate effectively in the new treaty's implementation.

In addition, the Blue Planet Prize grew out of activity from the 1992 Earth Summit in Rio. Endocrine disruption was not on that agenda. It is imperative that Endocrine Disruption gets on the Agenda of the 2002 Earth Summit—the Rio +10 high-level conference. I hope I can encourage every one of you here today to make this one of your near-term goals.

In light of the momentum already generated by the amazing discoveries that have surfaced through endocrine disruption research over the past decade, I have great hope that inner space research will go beyond learning more about signaling chemicals, embryonic and fetal development, establishing screens and assays to detect endocrine disruption, and come closer to assuring a cleaner womb environment for future generations.

And as we move into the inner-space age, we will also probe more deeply into the humanity in each one of us so that society gets its priorities straight and begins to think in terms of future generations, not just in terms of the bottom line, the Gross National Product, or the outcome of the next election. For it is going to take a major societal change in order to place the value of quality of life before the Gross National Product, and it would be much better if this change took place voluntarily rather than necessarily.

In closing, for our children's sake, let us make the new millennium the Inner Space Age. Thank you.

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## Profile

# Dr. Karl-Henrik Robèrt

Chairman of The Natural Step (NGO)

### Education and Academic and Professional Activities

- 1947 Born in October in Sweden.
- 1975 Medical license, Karolinska Institute.
- 1979 Ph.D., Medicine, Karolinska Institute.
- 1984 Swedish Hematological Association Research Award.
- 1985-1993 Division Head, Clinical Hematology and Oncology, Department of Medicine, Huddinge Hospital.
- 1987-1993 Chief Editor, Reviews in Oncology.
- 1989 Founded The Natural Step (NGO).
- 1991 Best Social Invention, Institute for Social Inventions, London, England.
- 1994 Stockholm City Council Prize.
- 1995 Professor of Resources Theory, University of Gothenburg.
- 1996 Swedish Forestry Association Prize.
- 1999 Green Cross Millennium Award for International Environmental Leadership.

Feeling an impending sense of doom about the degradation of the environment, Dr. Robèrt thought that to avoid further ravaging the environment it would be necessary to follow natural cycles and create a society in which resources were consumed within the scope of nature's processing ability. In short, he believed that we had to develop a sustainable society. Based on discussions with prominent Swedish scientists, he derived the following four systems conditions that would serve as the principles of a sustainable society.

In a sustainable society, nature is not subject to systematically increasing:

- 1) concentrations of substances extracted from the Earth's crust,
- 2) concentrations of substances produced by society,
- 3) physical degradation,

And, in that society:

- 4) human needs are met worldwide.

Then, based on these conditions, he created a new framework for corporations to determine the steps that they should take to help realize a sustainable society.

In 1989, Dr. Robèrt set up "The Natural Step" NGO in Sweden. This organization provides corporate management and policy makers with the decision-making standards and methodologies to formulate plans from a sustainable perspective. The organization is a collection of entities bound by these concepts and has won the approval of numerous companies and government bodies that are putting this thinking into action.

The advanced activities in this field of Dr. Robèrt's native land, Sweden, are serving as a model for the rest of the world. To date, The Natural Step activities have already spread to eight countries.

## The Second Arena

Dr. Karl-Henrik Robèrt

May 2001

The objective of The Natural Step (TNS) is to create more solid platforms for decision-making through systems thinking. A dialogue between scientists and decision-makers in business and science—ongoing since 1988—has created The Natural Step Framework. The Framework, with its “funnel,” the system conditions at its opening, the self-benefit in avoiding its walls, and the methodology to strive to compliance with the system conditions while improving bottom-line business, is described elsewhere in this book. The Natural Step Framework, created to further a more constructive dialogue and provide a basis for strategic decisions, has changed many firms and municipalities around the world.

But change doesn't only occur as a consequence of everybody taking part in a conscious dialogue. It is fine when that happens, but it would be a mistake to underestimate the importance of the small changes that occur as a consequence of much more subtle influences, a combination of direct and indirect spin-offs from the big and visible events. It is billions of communications in a web of interacting questions and answers that eventually lead to cultural change—like a slowly growing breeze that eventually fills a sail. I am proud to say that TNS has played a devoted and passionate role to fill that sail through the education of hundreds of thousands of decision-makers about the funnel, the self-benefit in avoiding its walls and the rationale behind our framework. Our impact is far greater than the relatively few firms and organizations that apply our framework as intended. The really systematic firms can merely be regarded as “laboratories” in which it has been demonstrated that it actually works, and as “locomotives” at the leading edge of societal change. And through their influence and guidance, the changing wind has become so much stronger than it would have been without their presence, through all the indirect effects.

But I am aware that we cannot just sit and wait for a slowly growing number of firms that apply a sustainability perspective to their work, and for the others to continue with their *ad hoc* programs even if they get somewhat more radical. Working *ad hoc* has been the most typical way during the 90s in general, and we can call that to be active in “Arena 1.” Whereas, the few systematic “laboratories and locomotives” that apply backcasting from a sustainability perspective—firms like Sångå Sjö Conference Hotel, Scandic, Swedish McDonalds, Interface, Collins Pine, Patagonia, Body Shop and a few more—are in Arena 2.

From a business perspective, the two arenas can be characterized as:

### **Arena 1 = Lantern-Navigation**

- Ethics, market, profitability
- Head of environment
- Environmental management system (EMS)
- “Eco-efficiency”
- Indicators/key-figures

In Arena 1, firms have realized that it will be necessary from an ethical point of view to take sustainable development seriously. Profitability will gain from this in the long run, partly due to the ethical reasons, partly because of higher “eco-efficiency” —waste is money. To that end, firms in Arena 1 have selected a head of environment and an environmental performance system. To demonstrate the seriousness of all this, they run a number of projects *ad hoc*. And they have a number of indicators and key figures to monitor progress for these *ad hoc* projects. Those projects and indicators are selected in terms of what the market likes or wants right now, and in terms of what legislators are likely to say soon. This is like orienting on the lanterns of other boats in an archipelago full of rocks, and will not be sufficient in the long run.

### **Arena 2 = Lighthouse Navigation**

- Systems perspective
- Social, ecological, economical sustainability
- Course-corrective investments
- Head of environment in management team
- EMS is business-strategic tool

In Arena 2, firms have realized that it will be necessary to have a sustainability perspective for planning. These companies generally talk more about social, ecological and economical sustainability, than about the “environment.” Profitability will rise only if objectives and strategies are planned with a backcasting perspective from principles that are robust enough to cover ecological and social sustainability. In those companies, the head of the environment is part of, or closely allied with, the management team. The EMS is a business-strategic tool, not a dust-collector on the book shelf of a frustrated “Head of Environment.” This is like orienting from fixed lighthouses, and the risks of hitting rocks further ahead are highly reduced.

In the new millennium, we need a new awakening of society at large, much in the same way as when Rachel Carson wrote her book. But the problem is that this time the sense of urgency is much less than it was then. Firms were then caught off-guard, birds were dying, and they didn’t know what to do about it. Today, many Arena 1 firms believe that they are in control just because they have a “green” manager and an environmental management system. However, there are probably few professional groups in society today that are more frustrated than green managers at large companies. They are rushing around screwing on filters and asking for higher budgets, whereas the dynamic top management team is running business more or less as usual. If the CEO is asked—for instance by journalists—reference is made to this

poor chap, who sits there in his green office with his EMS that nobody reads. I am not certain what will be needed to make the majority of firms want to break up with Arena 1 and make it to Arena 2. But I hope that we won't have to wait for more and more powerful build-ups of natural catastrophes to make it happen.

A somewhat paradoxical perspective may actually be the rescuer here. I think that social sustainability (system condition 4) may hold the key to our salvation. To be a contributor to the violation of that system condition will cause very serious backlash effects just like for the first three system conditions, and it is as bad a business idea in our funnel as anything ecologically linked to non-sustainability. However, most firms have not reflected on social non-sustainability, or how they are active parts of the problem in this aspect. This means that today's non-sustainable social make-up of modern society holds a potential for a "big bang" awakening—just like when Rachel Carson raised the first awareness of ecological non-sustainability. If the green movement plays its cards well, social sustainability may become the vehicle for a new dawning of urgency that may bring the whole sustainability perspective into focus. In fact, it is difficult to even perceive a successful cultural change, built on visions of an attractive sustainable society, without a deeper and systematic view also on ecological sustainability.

The protests against the World Trade Organization (WTO) in Seattle in Fall 1999 is an example of a possible dawning of a more powerful social awareness on the global scene. When I was invited to the Year 2000 World Economic Forum, I got further evidence that social responsibility is likely to build momentum.

### **World Economic Forum, Davos, February 2000**

I have many impressions and thoughts from this meeting, but I will restrict myself to two that can exemplify the differences in awareness of ecological and social non-sustainability, respectively.

### **The Greenhouse Effect**

A positive surprise was that scientific knowledge about global climate change seems to have finally reached decision-makers. It was commented on over again, and I didn't see one single example of an effort to sweep the issue under the carpet. A questionnaire amongst the delegates showed that a clear majority was of the opinion that the greenhouse effect deserves stronger political measures. The nebulous attitude that characterized mass-media discussions of global warming during the last years wasn't present. The general message was that we must cut down on the global use of fossil fuels by much more than half in a few decades in order to avoid increasing risks. This, of course, means even greater reductions in the industrialized part of the world.

During one of the seminars, the international head of Greenpeace, Tilo Bode, and the chairman of Shell, Mark Mudy Stewart, reached consensus on the need for significant reductions in fossil-fuel combustion. They also reached consensus that the road to success lies in a sped-up transition to other fuels, and that the only economically possible way is reduction in overall fuel use: in other words various means of improved resource efficiency.

## Global Social Inequity

Down the road from the Congress Hall, activists were smashing windows at the local McDonald's. President Clinton, in his address, spent considerable time on the growing gaps in the world, and warned that it would be a great mistake not to take protest activities of this kind seriously.

According to Clinton, the Davos meeting ought to sketch out attractive future scenarios where the gaps *have been* bridged, where programs for the transition ought to be designed to take us there (backcasting). The trustworthiness of the politicians when it comes to shaping such visions was, according to Clinton, limited. In other words, Clinton asked for help.

Perhaps we can look forward to more politicians realizing that the growing gaps between rich and poor are untenable and a threat to all. Isn't it even likely that this will be the case, in consideration of today's worrying trends?

- More and more people spend time on investing in shares on the stock market without having a clear idea in what way this is beneficial to society. Larger and larger sums of money are turning over in shorter timeframes. The short-term profits are generally without any linkage to human services or value-added. We are drifting further and further away from what work and being economical are all about. In short, money has taken on a life of its own.
- Heads of business, when asked on TV about their ambitions, are eager to testify that they are "serious" and trustworthy. In the terminology of the 90s, this has begun to mean that they *only* think about profit and shareholders. Almost nobody dares any longer to claim that he or she has more ambitions with his or her firm than earning money—no agendas for any other purpose. Almost without us noticing, money has changed position from being a means for society to become the goal itself; the only goal.
- Money is allocated to the sectors of society where the opportunities for growth and profit are largest. At the same time, schools and medical care are being deprived of resources. Who expects the teaching of kids and treatment of patients to grow in competition with the Internet? But isn't care for children and the infirm and the elderly the major sign of a culture?
- If, from time immemorial, cultures have been held together by "living stories of meaning," what is the story of our times? That everyone should take care of him- or herself? That economical growth is the tide that sooner or later will lift all boats—also the poor ones? We live in a world where we can phone anybody anywhere in a few seconds. Is it then reasonable to envision a rich and happy world—fenced in and surrounded by even more starving people than today's one billion of them, who do not even have access to safe drinking water or enough food? Is it even theoretically possible to expect this development to be possible?

The question now is not only a moral one, it is also an issue of common sense. Today, the rich part of the world seems to be more focused on consumption than on worthy global visions. If

that trend should be allowed to continue, we will fail to develop the wherewithal and institutions that are needed for the inclusion of the developing world into meaningful and secure prosperity. Is it possible that only the poor part of the world will be affected if we fail?

The TNS “funnel” denotes that the room for maneuver is diminishing due to non-sustainability. “Degrees of freedom” are systematically diminishing due to reduced productivity in ecosystems while demands on living systems increase. It is not difficult to imagine how the walls of this funnel will constrain those firms that are relatively responsible for creating the narrowing: green taxes, waste management costs, insurance costs, increased liabilities, et cetera. But in what way are social matters part of the funnel, and how will socially non-sustainable activities affect the individual firm? It is easy to foresee a series of events that could cascade into second- and third-order effects in a self-perpetual loop:

**1. Anxiety and tension.** The rich part of the world becomes less secure. A few examples:

- (i) Loss of culture and alienation. The graffiti seen on underground cars: “You destroy our future, we destroy your present.” Children have even started to kill each other. Money, instead of a living culture, is a bad substitute. Certainly there is reason to start seeing a connection?
- (ii) We violate our conscience and sense of self since we are violating the golden rule: “what you do not want others to do to you, you shouldn’t do to them.” We are, for instance, using more fossil fuels per capita than we would like Chinese people to do, and we buy resources from poor countries at such low prices that social costs are not paid for. Many people feel an increasing uneasiness and would probably be prepared for action if they only knew what to do.
- (iii) The costs—for instance of the United Nations—to deal with conflicts about water, small eruptions of violence, ecological refugees and famine catastrophes are increasing year after year.
- (iv) Many environmental consequences of poverty are already hitting the rich world indirectly. Examples include deforestation contributing to around 20% of the greenhouse effect and the loss of biological diversity and thereby future resources.
- (v) Worries have already started to influence “the market.” Examples are companies that have been stigmatized due to internationally inequitable behavior. Shell’s exploitation of poor people in Nigeria, for instance, is but one example that cost this company billions.

**2.** These worries, that of course have many more mechanisms than the ones discussed above, are causing the channeling of more money along new pathways in the market. Examples are:

- (i) Thirteen percent of funds in the United States were reported ethically invested at the Davos meeting in 2000. Although there is not much discussion yet, this means money is being withdrawn from one sector, industry or company, and being placed into another. Isn’t it likely that this trend will continue as long as the walls of the funnel continue to lean inward?

- (ii) Certain private funds are allocated directly to certain projects in the developing world. For instance, Bill Gates has donated billions of U.S. dollars to vaccination programs for the poor.
- (iii) Certain firms have started to launch projects in poor regions of the developing world. Shell, for instance, has recently started installing solar photovoltaics in South African townships using so-called “smart cards” costing residents no more than a month’s worth of kerosene.

3. The more good examples we get on the list above under Point 2, the easier it will be for proactive politicians to start acting. This is probably what Clinton meant when he asked for help in Davos. In a democracy, politicians have difficulties to take the lead setting goals in the beginning of a paradigm shift. For example, politicians cannot implement heavy taxes on fossil fuels until the alternative fuels exist on the market. A changing policy generally starts as a dialogue between proactive people and proactive firms. New political means, laws, money for welfare projects and institutions for social justice will only be feasible to implement when there is a growing political “market” for it. Then, good cycles will drive development much faster. It will be easier to put more good examples on the list above and then it will be even easier to speed up the political development.

For those firms and institutions that are today trying to hide behind the idea that it is far away to the have-nots, and that there is nothing that can be done anyway, there is a growing risk that the thinking will backfire. For those who want a brick wall between poor and rich, there is all the reason to contemplate another brick wall in our history, the Berlin Wall. The breaking down came with such surprising rapidity that all the defenders of the wall could not catch up.

The next Davos meeting in 2001 had a new overriding theme: “Bridging the Gap.” Clinton actually opened the way. Cultural change might eventually occur, fostered by the only “living story of meaning” I can think of at this point—the vision of an attractive sustainable society. A “Taking Care of the Planet Culture.” As far as I can understand, it’s not even feasible that ecological sustainability would be left out. It is my hope that we have just seen the dawning of it, and that the relative lack of social awareness of the green movement—that goes for The Natural Step too—is the reason why we have had to wait so long.

## Lecture

# Planning from Principles for Success

## — Lecture on The Natural Step Framework —

Dr. Karl-Henrik Robèrt

### A Framework for Strategic Planning

During its evolution, nature has slowly grown cleaner as a result of the workings of life. Plants have concentrated and organized matter on earth through the process of photosynthesis. This has enabled the development of ever more sophisticated life-forms, in an almost inconceivable complexity and diversity. With the appearance of animals, biodiversity registered another increase—with a parallel increase for plants. Because of their ability to move, animals distributed organic waste that plants could use. Animals also helped plants with pollination. In other words, nature evolved.

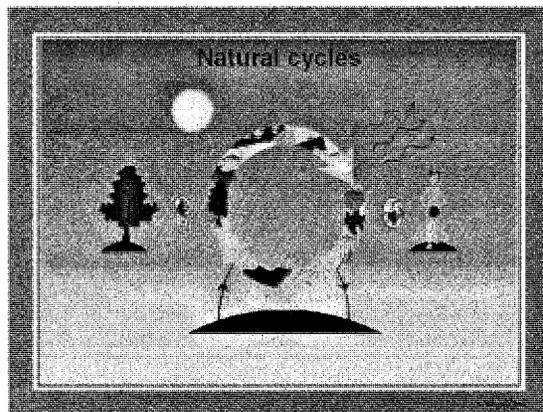


Figure 1. The human and natural cycles.

Sustainability and sustainable development only became important once people were affecting nature so that society's co-evolution with nature was no longer sustainable. Nature is complex. So is a description of all the environmental problems that follow from society's current non-sustainable course...

Environmental damage is not usually caused by a small number of 'hotspots,' but rather, from a host of diffuse sources. All serious environmental problems cannot simply be blamed on manufacturers and factories. Some causes have more to do with our behavior—the goods and services we consume, and the transportation we use. Besides, the effects of environmental damage are rarely direct. There is often a deferred effect. Once ecotoxins have been applied

in the production of our goods, it often takes a long time for them to be released. Nowadays, most people are aware of a great complexity in environmental problems. Many problems are now global rather than regional and it is difficult to find direct instances of cause and effect. This is the underlying reason for all the endless debate between scientists that we see and hear every day in the mass media.

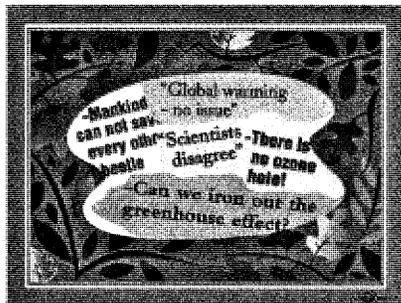


Figure 2. Newspaper clips.

Often, different environmental problems have a knock-on effect. Acid rain speeds up the leaching out of metals from the soil to waters, which, in turn, causes toxic effects in the ecosystems. As a rule, it's not possible to recognize today's environmental problems using our own senses. It's even more difficult to predict tomorrow's environmental problems lying dormant in the system. With this knowledge it is obvious that we need a *framework* to be able to handle complicated environmental problems.

### The Natural Step

I'm a medical doctor and a cancer scientist. Through insights from working with cells, I launched a consensus-building process amongst some of Sweden's top scientists. The objective was to come to grips with the confusion that came from all the complexity of the environmental problems that were caused by our non-sustainable society. To turn everything upside down in relation to the fascination over disagreement and polarities, I asked, "What can we agree on?" Impelled by an understanding of the value of establishing basic fundamental principles for the structuring of data in order to make better sense for decision-making, my colleagues merged forces to do their best. Imagining that if a society could share the same understanding of how a sustainable society could interact with the cycles of nature and thereby share the same principles for sustainability, then it could take on the challenge of sustainable development in a strategic way. The scientific consensus process yielded several benefits that continue to serve as societal drivers towards sustainability. The most touted is the first consensus document, which roughly outlines the way in which the cycles of nature work, how they are being disturbed, and that society—not least the individuals who are part of the problems rather than the solutions—will eventually pay prices for this economically, socially and ecologically.

Equipped with this quite unique document, I began to recruit the necessary players in

order to spread the news to a slightly larger audience—the entire Swedish population. Momentum was created in a step-by-step process, recruiting more scientists, then entertainers, then Swedish television, the government and eventually the Swedish King. This was enough for the sponsors to hop on board. As a result, a thirty-seven-page booklet emblazoned with *Det Naturliga Steget* (The Natural Step) and an audiocassette was mailed to every household in Sweden, 4.3 million copies, and thus the organization, The Natural Step (TNS), was born in April 1989.

### **The Natural Step and The Natural Step Framework**

Various activities that sought new and strategic social engagement and public education sprang up due to motivated individuals: the Environmental and Challenger trains (mobile educational and marketing trains that covered the country), the King's Challenge (a tetra-annual competition for the best eco-municipality), the Youth Parliament for the Environment (an annual TV broadcast event that engages around 50,000 students), and more and more municipalities (soon the majority of them) that adopted The Natural Step Framework as their planning platform for their Agenda 21 work. Another outcome, partly due to aspects of Sweden's cultural character, was the number of self-organized professional networks for the environment. These groups ranged in size from thirty to hundreds of people, and represented most major professions: scientists, engineers, doctors, nurses, et cetera. Academia, industry and informed actors produced a series of consensus documents, which outline an agreed-upon vision of the sustainable future of that sector.

### **The Natural Step Framework**

The Natural Step Framework is a methodology based on planning from a 'future sustainable perspective,' known as backcasting. Backcasting is a method of looking back from an imagined point of time in the future. To begin with, we envisage a successful result in the future. Then, we ask: "What can we do today to reach this goal?"

Planning with backcasting is especially effective if there is a high level of complexity, a pressing need for fundamental change and when dominant trends are part of the problem. As all three of these are currently very much in evidence, backcasting plays a useful role in planning for a sustainable future.

Nobody can look into the future, so it cannot be described at the detailed level. But at the principle level, we can *define* it! Backcasting must occur from *basic principles*, or *conditions* that need to be in place in *any* sustainable society. This is much like playing chess. It is backcasting from the principles of checkmate that provides the strategic framework of the game. The major achievement of The Natural Step is that we developed such a framework, which includes such basic principles for social and ecological sustainability, named "System Conditions." In this context, backcasting means planning from a "future sustainability perspective" by asking the following question: "What shall we do today to increase our chances to comply with the System Conditions tomorrow?"

The Natural Step works with organizations that want to become good examples and role models—firms, municipalities and other organizations—asking themselves this question. We

coach them *strategically* so that their programs for social and ecological responsibility will pay off also economically. To that end, organizations are trained to use The Natural Step Framework, which means to apply a sustainability perspective to planning, and then to move systematically and strategically in the right direction. With the help of a sustainability perspective, many organizations have been able to avoid the problem of “rushing after reality,” and “fixing” problems from principally non-sustainable planning. Thereby, they can successfully reduce costs, improve quality and identify new customers and markets.

The Natural Step Framework is a planning methodology with the following components:

The Funnel: Reflects society’s diminishing room for manoeuvre. The long-term prospects of organizations will improve if operations are steered in a sustainable direction, toward the opening of the Funnel.

The System Conditions: First-order principles that define a sustainable society (at the opening of the funnel).

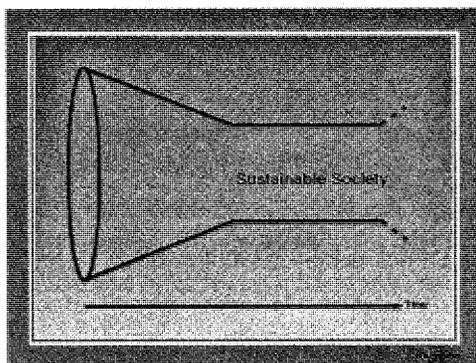
Strategy for Action: A four-step program where backcasting is used in a way that helps organizations to move toward sustainability while at the same time maximizing financial returns.

Below follows a comprehensive description of these components.

### **The Funnel**

Life-sustaining natural resources are subject to increasing deterioration from human activity. Species extinction is gathering pace. Productivity of forests, agricultural land and fisheries are declining. To harvest or catch as much as we did last year, we have to put in more resources—to obtain the same amounts of food, wood and other raw materials, we need bigger fishing boats, more energy, more pesticides and more fertilizers.

The reason for this reduction in productive potential is that we are polluting and displacing nature in various ways. Renewable resources are being used up at such a rate that nature does not have time to build new ones. In the same time, we get more people on earth and the gap between rich and poor is widening. It’s as if civilization is moving into a funnel whose narrowing walls demonstrate that, in the quest for good health, welfare and economics, there is less and less ‘room for manoeuvre.’



**Figure 3.** The funnel.

There is a potential self-benefit in being part of the solution rather than the problem. While sudden economic setbacks may be viewed as 'bad luck,' they are usually caused by earlier investments in techniques or activities that go against the conditions for a sustainable society. Though certain companies can still earn money from not taking part in our shared responsibility for the world we live in, the statistical chance of avoiding the consequences decrease over time. A new way of planning must be put in place to avoid problems such as:

- higher raw materials costs,
- higher energy costs,
- harsher environmental legislation,
- differentiated taxation,
- rising insurance premiums,
- lower credit ratings,
- criticism in the media,
- eroded public confidence,
- loss of environmentally aware customers,
- recruitment problems and difficulties in retaining quality staff.

Although long-term financial results will improve if operations are steered in a more sustainable direction, they also need to be profitable even in the short term. How short term and long term can be merged into a strategic program is described under the two following aspects of The Natural Step Framework.

## The System Conditions

To be able to handle the complexity of environmental problems, we must move from assessing impacts in nature from human actions to finding the root-causes for these effects.

Can we sum up the root-causes for non-sustainability? There are essentially only three mechanisms by which human society can damage nature.

- Nature is damaged if concentrations of substances that are extracted from the Earth's crust are continually rising because they are dispersed in nature faster than they are returned (re-deposited in the Earth's crust).
- Nature is damaged if concentrations of substances produced by society are continually rising because society disperses them faster than they can be broken down and built into new resources by nature (or deposited in the Earth's crust).
- Nature is damaged if it is continuously degraded by physical means. This occurs either by extracting more than nature can build up again (for instance, more timber or fish than can be regenerated) or by other forms of ecosystem manipulation (for instance, altering the water table, soil erosion, unforeseen accidents with genetic manipulation, over-harvesting or covering fertile land with asphalt).

By looking at these three ways of damaging nature, and then adding the word 'not' to all of them, The Natural Step has defined the three first-order principles that establish the framework for a sustainable society. A sustainable society is characterized by the fact that it is good at satisfying human needs, but *within* this framework. The fourth fundamental principle takes into account the ability of a sustainable society to satisfy human needs everywhere.

## The Four System Conditions

In the sustainable society, nature is not subject to systematically increasing...

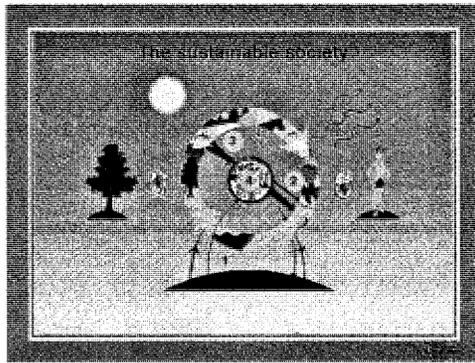
- 1....concentrations of substances extracted from the Earth's crust
- 2....concentrations of substances produced by society
- 3....degradation by physical means

and, in that society. . .

- 4....human needs are met worldwide.

These four basic principles, known as the four System Conditions, make up a framework defining the prevailing conditions that will apply in any sustainable society.

In the illustration below, the four System Conditions are shown in relation to natural cycles and human society as an integrated system where flows are balanced and "left over matter" does not increase in concentration in nature.



**Figure 4.** The sustainable society: natural cycles (the larger circle) surround society and define the limits which we have to live within. In a sustainable society, plants (on the left-hand side) build up enough renewable resources to satisfy consumption by animals and humans (on the right-hand side). Various agents break down the waste from animals, thus making it available, as a resource, to plants. The sun provides energy, and heat radiates into the universe. Society lives partly on small flows of metals and minerals from the earth's crust (1) and on larger flows from nature's production (3). A flow of substances produced in society leak into nature, but no faster than they can be broken down or assimilated in the natural cycles (2). In this society, resources are recycled and used efficiently so that human needs can be fulfilled effectively (4).

### Strategy for Action

Firms that are applying The Natural Step Framework, structure the work in the following way:

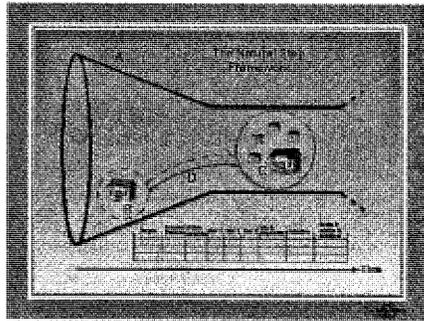
#### *A Sharing The Natural Step Framework*

Discuss the Funnel, and the System Conditions, and the *A,B,C,D*-analysis that is presented below, among all participants who are going to be part of developing the program for transition. It is important that critical questions are allowed, so that the team eventually has a clear picture of how much they share on the principle level. This refers to the strategic competence to move in the direction of social and ecological sustainability, and the economical self-benefit that lies in doing so.

Firms that have done this, generally define their overall objectives in the following way:

*Our ultimate sustainability objectives are to:*

1. *...eliminate our contribution to systematic increases in concentrations of substances from the Earth's crust.*
2. *...eliminate our contribution to systematic increases in concentrations of substances produced by society.*
3. *...eliminate our contribution to the physical degradation of nature through overharvesting, introductions and other forms of modification.*
4. *...contribute as much as we can to the meeting of human needs in our society and worldwide, over and above all the substitution and dematerialization measures taken in meeting the first three objectives.*

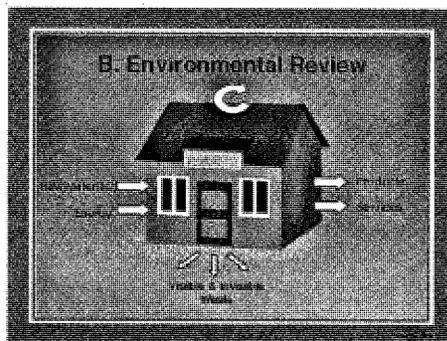


**Figure 5.** The Natural Step Framework.

**B How Does the Organization Look Today?**

To find out how our organization is impacting the environment, we need to carry out an environmental review (see B in Fig 5). This review will provide the foundation for specific environmental targets and planning. The environmental review should map out such flows and practices in the organization that are critical from a sustainability perspective— with regard to the *ultimate sustainability objectives* of the organization (see above).

An organization is like a box with various flows going into, or coming out of it (see Fig 6). If these flows are analyzed in relation to the System Conditions, we end up with a list of problems, or environmental aspects, that have a sustainability perspective (not only a “today’s impact perspective,”— such effects in nature or society—occurring from violation of the system conditions—that we are already familiar with). We already know that nothing disappears, so it seems logical to start by looking at the flows of raw materials and energy being imported into ‘the box’. That way, we can eventually relate these to what is being exported.



**Figure 6.** Environmental review.

It's important to involve all employees, as everyone has some impact on the flows of raw materials and energy. Whoever is responsible for a particular task or process should know what flows arise out of that process. To achieve this, the same individual must be drawn into the process of identifying problems and developing specific measures, and then be responsible for the implementation of those measures. At The Natural Step we have found the best results are obtained if employees themselves carry out the environmental review – backed up by resources, such as questionnaires, that examine the position of the organization in relation to its ultimate sustainability objectives.

### **Sustainability Objective 1**

*Examples of problems* include rising levels of heavy metals in the soil, phosphate in lakes, sulphuric acid in forests and carbon dioxide in the atmosphere. Nature cannot sustain systematic increases of any substance. Every single atom of mercury, lead, zinc, copper or coal that we extract from the Earth's crust, must end up somewhere.

*Make a list* of the critical flows of your firm, such flows that are likely to contribute to problems of this kind, problems with reference to sustainability objective 1.

### **Sustainability Objective 2**

*Examples of problems* include a number of non-biodegradable substances not found in nature, such as chlorofluorocarbons (CFCs), polychlorinated biphenols (PCBs), many pesticides, dioxins, bromide anti-flammables and many additives in plastics such as chlorinated paraffins. The manufacturing of substances is either intentional (such as in the chemicals industry) or unintentional (such as by-products created during waste incineration). Substances not broken down and integrated into the natural cycles will build up in the environment. When emissions are large, naturally occurring compounds may also increase in concentrations. For instance, NOx that cause problems such as eutrophy, acidity and ozone depletion.

*Make a list* of the critical flows of your firm, such flows that are likely to contribute to problems of this kind, with reference to sustainability objective 2.

### **Sustainability Objective 3**

*Examples of problems* include clear-cutting of forests, spreading deserts, loss of nutrients, construction of roads and buildings on fertile land, over-fishing in seas and lakes, mass tourism in pristine areas of nature and damage to sub-soil water flows.

*Make a list* of the critical flows of your firm, such flows that are likely to contribute to problems of this kind, problems with reference to sustainability objective 3.

### **Sustainability Objective 4**

*Examples of problems* include the uneven distribution of resources within humanity, leading to problems like famine and lack of safe drinking water in large regions of the world at the same time as the industrialized world spends more resources than we want on, for instance, traffic jams, and suffers from alienation and loss of cultural meaning.

*Make a list* of the critical flows of your firm, such flows that are likely to contribute to

problems of this kind, problems with reference to sustainability objective 4.

### ***C How Does the Organization Look in a Sustainable Society?***

Here, we develop a vision of how a sustainable organization might look. The point of the exercise is to 'lift the vision,' look for solutions and free oneself from preconceptions based on prevailing conditions. The way to approach this is to learn to envisage the organization as a service provider. What utility is the customer really looking for? What needs are fulfilled by our organization? How can we satisfy the customer's needs in a sustainable society? Are we selling cars or mobility? Are we selling kilowatt-hours or light and heating? In what way is fairness at the global level important to our activities?

Next, we list every conceivable means of meeting the needs of our customers without compromising our ultimate sustainability objectives. It is not enough to take action to avoid the mistakes that have already started causing environmental damage.

If this process is overseen with proper care, there can be far-reaching consequences and opportunities. The organization may even, as a result, change its mission statement and find new and promising market segments.

#### **Sustainability Objective 1**

*Sustainable options* are to switch to renewable fuels and materials such as wood, fibers, ceramics, glass, et cetera. We can also discriminate in favor of metals commonly found in nature. The more common a metal is in nature, the more freely we can use and recycle it without fear of rising concentrations. Aluminum and iron, for instance, are considerably more common in nature than copper and cadmium. Using metals efficiently and establishing sophisticated recycling systems, are other ways of avoiding rising concentrations in nature. Even in a sustainable society, it may be necessary to increase mining of particular substances in the short term. An example of this would be certain rare metals needed in solar cells—and later recycled, of course. The effects would be beneficial, as solar cells reduce the need for non-renewable fuels.

*List solutions* with reference to the general description of options presented above, make a list of all the options with reference to sustainability objective 1 that would be available for your firm. It is important that this is done through brainstorming. Everything that is theoretically possible should be listed.

#### **Sustainability Objective 2**

*Sustainable options* include the phasing out of substances that do not readily biodegrade and are not commonly found in nature. It may also be necessary to control a range of other substances that, even though biodegradable, are nevertheless building up in nature because of excessively high volumes in use. This can be done by using substances efficiently and establishing sophisticated recycling systems. Even in a sustainable society, it may be necessary to occasionally use non-biodegradable substances not normally found in nature. Such as, for instance, important pharmaceuticals, which can later be separated from body secretions. However, this will only apply if there are no better alternatives that are safe to use without constant monitoring.

*List solutions*, i.e. – with reference to the general description of options presented above – add to the list of solutions all the options with reference to sustainability objective 2 that would be available for your firm. It is important that this is done through brainstorming, i.e. everything that is theoretically possible should be listed.

### **Sustainability Objective 3**

*Sustainable options* are to buy sustainably grown food and raw materials from well-managed forestry plantations. By locating new factories on the foundations of old ones and planning all construction with respect for nature, we can minimize our presence in nature. Another sustainable option is to become more efficient – for example, companies can plan strategically to reduce the need for long-distance transportation.

*List solutions*, i.e. – with reference to the general description of options presented above, add to the list of solutions all the options with reference to sustainability objective 3 that would be available for your firm. It is important that this is done through brainstorming, i.e. everything that is theoretically possible should be listed.

### **Sustainability Objective 4**

*Sustainable options*. These all include measures to increase the human utility per resource unit. Examples are to find completely new, and more sophisticated ways of meeting the same human needs. For instance, IT technologies can substitute for transport and provide more human benefits at the same time. Other examples are various ways of reducing resource flows, and thereby costs, to make such products that are important for human needs available also for relatively poor people. For instance, filters that can manufacture drinking water from polluted water, rather than exporting drinking water at large financial and ecological costs. Other options are to move into markets in developing parts of the world, and to find ways of adding social costs to prices of resources purchased from such areas.

*List solutions*, i.e. – with reference to the general description presented above, add to the list of solutions all the options with reference to sustainability objective 4 that would be available for your firm. It is important that this is done through brainstorming, i.e. everything that is theoretically possible should be listed.

## **D Strategy for Action**

Environmental programs with targets and measures to improve profitability are designed in this step.

By choosing measures from C that stand up favorably to the key questions outlined below, long-term and short-term profitability are linked – and each step becomes profitable in itself:

1. *Are we moving towards our objectives?* Each suggested measure is assessed against the environmental objectives. Does the measure reduce our dependence on, for instance, heavy metals (sustainability objective 1) or non-biodegradable substances not usually found in nature (sustainability objective 2)?
2. *Are we creating a flexible platform for further improvements?* It's important to choose

solutions that are as flexible as possible, so they can be further developed in a sustainable direction. Otherwise, we might end up in a cul-de-sac. If technical or economic conditions change, investments in flexible solutions will ensure that adjustments do not bring punitive costs. Can our new, lean-burn engine be modified to use renewable fuels? Is this expensive plant for recycling of heavy metals really a smart decision – shouldn't we substitute those materials for others instead?

3. *Will the measure bring quick enough financial returns?* We prioritize 'low-hanging fruit' – in other words, measures that bring improved profitability even in the short term or in other ways generate comparatively quick returns on investments. Does the measure bring resource savings? Can this measure help improve our sales figures? Can this measure help us reach a new market segment? Can it generate profits through new marketing strategies to increase customer brand loyalty?

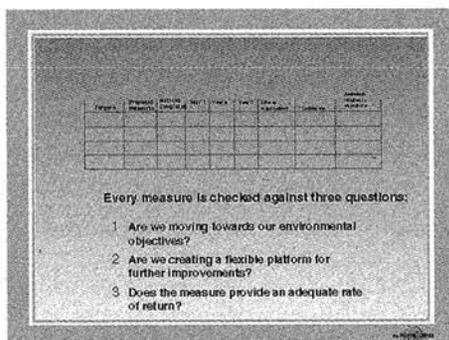


Figure 7. Strategy for Action.

By using The Natural Step Framework in our planning, we can choose investments and measures with maximum flexibility in the long term and maximum profitability in the short term. With clever planning, it's possible to go forward without bringing yesterday's problems into the future. Realistic measures applied today will affect only the *speed* of change, not its *direction*. That is the essence of systematic planning through backcasting.

The leaning walls of the funnel will systematically increase the relative advantages of proactivity and pose increasing risks for those who are late in the transition. So, The Natural Step's framework focuses on "backcasting from success." This complements the more traditional way of planning—"forecasting from problems." The traditional forecasting perspective provides a planning procedure with relevant information on today's impacts on nature, and how these impacts influence current market trends. This approach is oriented around current trends, and responds to actual market demands from a competitive point of view. The weakness in solely applying a forecasting perspective in a planning procedure is that it deprives the

planning process of a sense of direction and may lead into blind alleys. Incremental changes can sometimes be counter-productive, even if they are reducing today's impact on nature. Incremental changes of an old system can lock up resources that could be used in a strategically smarter way. Finally, using forecasting approaches alone makes it difficult to deal with tradeoffs. When combining the two perspectives, backcasting gives the direction of planning, and forecasting can provide important information on relevant market trends and sometimes also influence the choice of smart "stepping-stones." In the following, a few concrete examples from business will elucidate this distinction.

### **Some Examples of Applying The Natural Step Framework**

The Natural Step is non-prescriptive. This means that business examples are all provided by individuals and firms applying the The Natural Step framework, whereas The Natural Step as an organization only uses such examples to make it easier to understand the utility of the framework.

#### **An Example from Electrolux**

An example of concrete planning comes from Electrolux, which started the planning to get rid of CFCs by forecasting. The first option they considered was to substitute HCFCs for CFCs since HCFCs have a lower impact on the ozone layer. This plan was further supported by an LCA that had the forecasting-perspective. It had revealed a tradeoff between HCFC on the one hand (with its uncertainty on the future market), and the high efficiency of HCFC-produced insulation on the other. Considering that the main environmental impact from a refrigerator is not during its production (relatively small amounts of HCFCs), but during the time it is used (relatively large amounts of emissions from the energy-sector), this forecasting analysis had favored HCFC technology. However, by applying backcasting from the system conditions, the management team of Electrolux realized that the switch to HCFC would imply an expensive transition into a blind alley, since there was no room for the relatively persistent HCFCs in their future scenarios (based on system condition 2). So instead they chose a "flexible stepping stone" by using the chemical R134a as an intermediate step. This technology fit in well as a flexible platform from which to move to the next generation of hydrocarbons and, at the same time, R134a fit in well with current trends in the market. Electrolux was first in launching a whole family of freon-free refrigerators and freezers. The result was increased market shares in several important markets and relatively higher revenues from those particular products.

#### **An Example from IKEA**

The following example comes from Russel Johnsson, head of environment at IKEA at the time. Replacing an incandescent lamp with a CFL (Compact Fluorescent Lamp) will give considerable savings in energy consumption and electricity costs (roughly a factor of 5) and a considerable increase in product life (factor of 8-10). But the high price has been an obstacle for the private households to dare to prove these facts to themselves in practice. The typical price level in Sweden at the time was 120 SEK (15 USD) for an 11 W CFL (corresponding to 60 W incandescent lamp). Another problem is that CFLs have higher mercury content than incan-

descent lamps.

The trade-off problem is between higher use of mercury (sustainability objective 1), lower expenditure of energy (sustainability objective 1 and 2) and higher costs for the lamps lowering their availability to the public (sustainability objective 4). A more creative methodology than trying to estimate if the impacts outweigh the benefit, is to start the planning procedure from a point where the tradeoffs don't exist—backcasting from compliance with the system conditions. In short, these were the steps to move in that direction:

Russel Johnsson: "We identified a producer who could provide a good-enough combination of the listed criteria to serve as a platform. We wanted a good reliable CFL with a maximum of 3 milligrams of mercury per lamp, which can be compared to the requirements in the European Union environmental labelling system for such lamps, which is a maximum of 10 milligrams on the global market (factor 3). A Chinese manufacturer, outstanding both from product design and production technology points of view, could meet those requirements at the same time as he was competitive enough on price.

We let this producer and his competitors know that as long as he would be ahead of his competitors as regards price, energy expenditure and mercury contents, he would continue being a supplier to IKEA.

During the fall of 1997, we started the Swedish marketing campaign for CFLs. It consisted of the following steps, which would bring us further in the right direction:

- (i) Price cuts to 1/3 for the 11 W (ca 5 USD) and less than 1/2 for the other lamp sizes.
- (ii) Cooperation with the largest Swedish environmental organisation, the Swedish Society for Nature Conservation (SSNC), around a public information campaign about energy (and cost) saving possibilities for households.
- (iii) Advertising in all major daily newspapers, offering all households to collect (during a two-week period)—free of charge—an 11 W CFL in our stores in order to convince themselves that CFL is a very profitable choice for their homes. Somewhere between 500,000 and 600,000 lamps were given away.
- (iv) Before launching the campaign we visited, together with SSNC technical expertise, our CFL supplier in China. We met their management, made a thorough review of the factory with special focus on the company's environmental management system and practices, work and worker's conditions. We also visited the supplier's RD&E department and discussed possibilities for further reducing the mercury content and other potential environmental improvements. We documented our visit on video and edited video cassettes were later distributed to all our Swedish stores.
- (v) We informed customers about the very serious environmental dangers with mercury and offered to take back (free of charge) all their used light sources containing mercury to IKEA stores. We made a contract with a major recycling company (RagnSells) to take care of all such returned light sources with mercury, including all those we generate ourselves in stores, warehouses and offices. 98%

to 99% of the mercury is recovered by a specialist company in Germany. Together with SSNC, we made a thorough review of this company also and documented it on the video cassette mentioned above.”

As a result of this campaign, the private household sales of CFLs in Sweden have increased considerably. The competition had to decrease their prices. Our CFL sales have increased. IKEA’s campaign has been good for everybody—for the customers and for the country—except the manufacturers and importers of incandescent lamps. If every Swedish household replaced 20 pieces of 60 W incandescent lamps with 11 W CFLs, the resulting yearly energy savings would equal the production of one of the Swedish nuclear reactors.”

### **How Does The Natural Step Framework Relate to Tools for Sustainable Development?**

We have presented a general framework to plan for sustainability. This framework follows from principles for how a system is constituted (ecological and social principles), and contains principles—the system conditions—for a favorable outcome for the system (sustainability), as well as principles—strategic principles—for the process to reach this outcome (sustainable development). The system conditions define the favorable outcome and direct problem-solving upstream toward problem-sources. A program of activities is then constructed by back-casting from defined outcomes to the current problems. This should be followed by “metrics,” which are various concepts for measuring and monitoring the activities so that those are really complying with the strategic principles to reach the favorable outcome in the system we have just described.

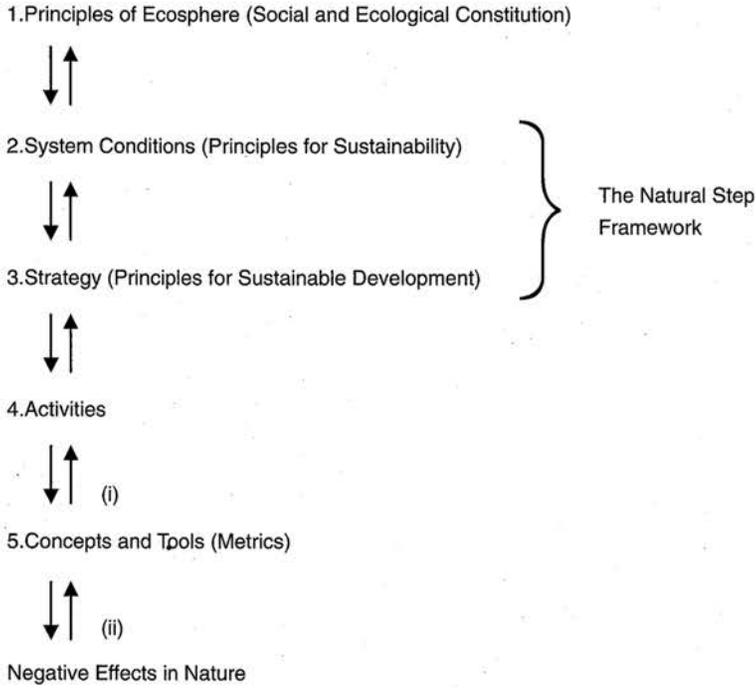
Most concepts and tools for sustainable development function as metrics, including Life Cycle Assessment (LCA), Ecological Footprinting (EF) and Factor X. When used in a strategically smart way, those tools are selected and designed in a way that helps the firm to actually reach its environmental objectives. A framework such as The Natural Step Framework is a methodology to create a sense of direction to the planning, and tools are then used to see to that the process actually complies with the overall planning.

An Environmental Management System (EMS), like ISO 14001 or EMAS, is an administrative vehicle that should systematically align a firm’s specific outcomes, activities and metrics with a general framework for sustainability. From a strategic point of view, metrics should measure alignment of activities with the principles contained in a framework for sustainability.

Of this, it follows that a framework is not an alternative to various tools for metrics. We need them all because they represent different interrelated levels of strategic planning. (Fig. 8) Imagine the analogy of running an airplane where:

- the firm is the airplane,
- the framework is the guidelines for planning this particular journey (to sustainability), including the map with the objective, plus a description of the principles for reaching that objective,
- the EMS is the manual and checklists needed to handle that specific airplane in line with the framework,

- the activities are everything that takes place on board,
- and the metrics are performed with the instruments needed for that airplane on this route, so that the activities comply with the plan for the flight.



**Figure 8.** Hierarchical relationships between principally different levels of planning in a complex system.

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