EA SUSTAINABLE DEVELOPMENT

ENVIRONMENT AGENCY

the NATURAL STEP

A Framework for Sustainability

PVC

An Evaluation Using The Natural Step Framework

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Table of Contents

Summary

Sustainable development acknowledges that the world's resources are diminishing whilst population is rising, diminishing the capacity of all enterprises to operate. This challenge is inevitable and unavoidable, but presents both opportunities and threats. The Natural Step (TNS) framework uses scientific principles to define sustainability - the capacity to continue indefinitely - in unambiguous terms. This study evaluates PVC from this sustainability perspective, establishing a number of substantive challenges.

The study does not focus on progressive improvements in eco-efficiency, with which the industry has made significant progress in recent years in reducing emissions of toxic substances, reducing energy consumption and eliminating certain additives. The recently-developed *Environmental Charter for UK PVC Manufacturers* and *Eco-efficiency Code of Practice for the Manufacture of PVC* being adopted by the UK PVC manufacturing industry marks an important incremental step on the road towards sustainability through the progressive reduction of these environmental impacts. However, the steps currently envisaged are insufficient to move the industry to a genuinely sustainable position.

Nor does this study compare PVC to other substances, although it is recognised that alternatives cannot be assumed to be any more or less sustainable given current manufacture, use and disposal practices. Comparison would not be helpful in maintaining the focus of the PVC industry on the substantive challenges that it faces.

PVC has brought major economic and social benefits, for example in the medical and construction industries. However, sustainability is an inevitable challenge, and so the issues that it raises must be addressed as a matter of priority. This analysis using the principles of TNS measures the life cycle of PVC against the ultimate goal of full sustainability, offering the PVC industry a process by which it can establish, in conjunction with key stakeholders, a programme for moving towards sustainability. This will help the industry move from a reactive to a proactive position, and help to encourage the necessary innovation to face up to the ultimately inevitable challenge of sustainable development. This challenge is unavoidable if the industry is to assure its long-term future. As with virtually any manufactured product today, including current alternative materials to PVC, there are many breaches of the System Conditions.

Using the principles of The Natural Step, it is possible to conceptualise a future in which PVC could be considered sustainable, although realising this vision in practice raises some fundamental challenges for the industry to face. To make progress towards PVC becoming genuinely sustainable, the industry should:

- **commit itself long-term to becoming carbon neutral.**

- **commit itself long term to a closed-loop system of PVC waste management.**

- **commit itself long-term to ensuring that releases of persistent organic compounds from the whole life cycle do not result in systematic increases in concentration in nature.**

- **review the use of all additives consistent with attaining full sustainability, and especially commit to phasing out long term substances that can accumulate in nature or where there is reasonable doubt regarding toxic effects.**

- **commit to the raising of awareness about sustainable development across the industry, and the inclusion of all participants in its achievement.**

PVC manufacturers and those dependent upon PVC products face a major challenge, including aspects of manufacture, use and disposal, if PVC is eventually to meet the sustainability criteria articulated by the four System Conditions of TNS. Given the distance of the PVC industry, and indeed of the whole of society, from the ultimate goal, there will be no "quick fixes" in a genuine commitment to achieving sustainability. Nevertheless, a commitment to long-term sustainability, and identifying and implementing those steps that can be taken today that lead incrementally towards that longer-term goal, will help in setting a timetable for addressing the remaining challenges. Deferring decisions and action indefinitely will serve only to confirming existing suspicions that may exist about "green-washing" and the lack of a serious commitment to sustainable development by those reliant upon PVC. Existing agreements and pressures, including for example European legislation and recommendations by the Oslo/Paris Commission, already contain specific targets which should inform this process.

The benefits of a commitment to sustainable development include avoiding locking capital up in short-term reactive solutions that might themselves have no place in a future sustainable world. A proactive approach also helps avert constant attack from those caught up in single issues. By accepting the challenges of change laid out in this report, the industry would be in a position to commit itself to a programme of sustainable development.

PVC was also the subject a **2020 Vision Seminar**, the second in a collaboration series run by The Natural Step in the UK and the Environment Agency to seek consensus on contentious issues. An earlier draft of this report formed the major input to the seminar. The 2020 Vision process used The Natural Step framework to address the question *"What is the place of PVC in a future sustainable world?"* in a closed meeting of thirty-six invited experts, engaging in structured dialogue leading towards consensus positions. Outcomes of the seminar included: broad agreement about the importance of addressing sustainable development; specific challenges posed by PVC (including the need to address the "five challenges" outlined in this report); the need for more sustainable processes and materials; the need for the industry to change; and the need to establish timetables for dealing with the issues raised. One of the key points of agreement was that the PVC industry cannot achieve the end-goal of a sustainable PVC life cycle in isolation. There is a need to show leadership in engaging stakeholders across society. There was also concern that equal scrutiny was not being given to all materials. This is both a matter of a "level playing field", as well as a prerequisite for tackling sustainable development and avoiding "knee-jerk" reactions against materials targeted by the media.

I. Introduction

The PVC Coordination Group, combining representatives of major UK retailers and the two UK PVC manufacturers, has been studying the environmental impact of PVC since 1996 (see the following section Background Information). In 1999, they commissioned a study of the industry from The Natural Step (TNS) office in the UK. As a parallel exercise, The Natural Step in the UK, in collaboration with the Environment Agency, ran a "2020 Vision" to broaden the debate and work towards consensus about the place of PVC in a sustainable future. This report presents the findings of both the main PVC study and the principal outcomes of the "2020 Vision" seminar.

The TNS Framework and the Approach to Sustainable Development

The TNS framework is a science-based set of learning tools helping organisations understand and get to grips with sustainable development. (For a more detailed summary of the TNS approach, refer to Appendix 1: About the Principles of The Natural Step.) By establishing the scientific basis for sustainability, the TNS approach removes the ambiguity that has built up around the term "sustainable development" in the wider media; it also focuses thinking on the ways in which the industry will have to change to meet the incontrovertible requirement to become fully sustainable. This evaluation addresses the question "*How could PVC be part of a sustainable future?*", and the TNS approach presents this substantive challenge as an opportunity and not merely a threat.

In tackling this question, it is important to point out that "sustainability" means something quite different from "more green". We live in a world where neither the unrestricted use of natural resources nor impacts on human populations can any longer be taken for granted. Human population is rising and placing extra pressure on diminishing resources, whilst public concerns, supply chain pressures, legislation, capacity for waste disposal and a host of social and economic forces increasingly challenge the ways we do business. The journey of sustainable development is ultimately unavoidable for business, whether undertaken proactively or by compulsion.

Sustainable development is therefore perhaps the greatest business challenge and opportunity for the future. If these statements appear radical, just consider that, 15 years ago, few would have predicted the enormous changes which the PVC manufacturing industry has made, whether proactively or under pressure, on for example organochlorine and other plant emissions, energy efficiency or handling packaging waste.

The four System Conditions of TNS, which collectively represent a holistic and science-based model of sustainability, provide the framework used in this evaluation. The TNS framework – the strategic tool of TNS – helps specialists to identify ways of making progress towards the longer term goal of sustainability across the whole PVC life cycle, including the material and the processes entailed in its production. Application of the TNS framework tells us whether it is possible to envisage the product/process ever becoming sustainable and, from that fundamental analysis, effective planning and action may follow. Such a strategic approach also enables decision-makers to set a proactive agenda, based on clear business grounds. An approach based upon an informed strategic vision is ultimately cheaper, and helps avert the short termism of "knee jerk" reactions to single issues which may result in no real progress towards sustainability.

About this Evaluation

This study is therefore not about furthering the progressive improvements in eco-efficiency with which the industry is already making progress. Such progress will no doubt continue, and will also include comparable social and economic improvements. Neither does this study seek to offer detailed analysis of the technical aspects of the PVC life cycle, or to provide specific solutions to many of the problems raised (breaches of the System Conditions). It aims to establish a vision of a future sustainable PVC industry, clarify the challenges and dilemmas facing the industry, and broadly indicate the ways ahead.

It is not the primary task of this report to identify technical solutions. The main purpose of this report is to highlight unsustainability, and the thinking that should guide the search for more sustainable alternatives. However, some examples of possible alternative approaches are provided to help the thinking process.

The challenges posed are formidable. Technical solutions to many of them do not currently exist. Indeed, there is no starting presumption that PVC can inherently form part of a future sustainable world. The economics for making many of the radical changes are currently not favourable in the short to medium term. All this is accepted. However, sustainable development is a challenge that is not going away, and presents substantive opportunities as well as threats. As a basic minimum, the advantages of being proactive surely outweigh the benefits of inactivity, being forced onto the back foot, responding on an issue-by-issue basis to media attention, organised social campaigns and political pressure. This investigation has highlighted areas where radical changes will be required in the longer term, and suggested some areas for short/medium term action.

The key questions explored in the study are:

- **Is the PVC industry currently sustainable?**
- **If not, is it moving in the direction of increased sustainability?**
- **What steps must it take to become sustainable?**

The 2020 Vision Seminar

As with many contentious issues, the debate about PVC has been polarised and frequently vociferous. The **2020 Vision** process, a collaboration between The Natural Step in the UK and the Environment Agency, uses the four System Conditions of The Natural Step Framework – the science-based model of the sustainable cycling of matter and energy on this planet and an associated set of tools. These were used as a helpful "systems thinking" approach and an appropriate framework to structure this debate in the context of the place of PVC in a future sustainable world. There is a report of this consensus-building seminar in Part V. The 2020 Vision Seminar and its Key Outcomes; a previous draft of this report was used as the key technical input to the consensus-building.

Timing

This report does not set a timetable for taking steps towards sustainability.

A true commitment to sustainable development must acknowledge that the programme cannot comprise merely "quick fixes". We live a world that is far removed from sustainability, and may realistically be a generation away from its achievement. The knack is to commit to long-term sustainability, identify and implement those steps that can be taken today that lead incrementally towards that longer-term goal, and to set a timetable for addressing the remaining challenges. Deferring decisions and action is not helpful, merely confirming suspicions that may exist about "green-washing" and the lack of a serious commitment to sustainable development.

Detailed time scales for implementing steps towards sustainability are a matter for determination by the industry and its partners, and must be factored in to investment plans. Targets agreed in European legislation are already focussing attention on priority actions that might for the next steps in a sustainable development timetable. Specific agreements by OSPAR[1], including for example the deadline of the year 2020 for eliminating emissions of persistent organic substances, endocrine disruptors and other substances of similar concern, and the closer deadlines for elimination of mercury emissions, also help establish priorities.

The benefits of a commitment to sustainable development include avoiding locking capital up into short-term reactive solutions that might themselves have no place in a future sustainable world. A proactive approach also helps avert constant attack from those caught up in single issues. By accepting the challenges of change laid out in this report, the industry would be in a position to commit itself to a programme of sustainable development.

The Structure of this Report

As indicated in the Table of Contents, the flow of this study begins with identifying breaches of the four System Conditions of TNS across the PVC life cycle (including a consideration of the steps already being taken or anticipated by the industry). This "gap analysis" supports a preliminary examination, to be developed further with representatives of the industry and other users of PVC, of the possible long-term sustainable vision for the product.

Such a vision should include suggestions for new manufacturing options, improved recycling, and the broad range of issues entailed across the entire life cycle of the plastic. The extension, further development and practical realisation of that vision is a matter for future phases of the "PVC Project" study.

[1] The *Oslo/Paris Commission for the Prevention of Pollution in the North Sea* (OSPAR or OSPARCOM) is a non-statutory Commission with ministerial representation, and is strongly influential upon European Union and national policies in Europe.

II. Background Information

PVC Coordination Group: The Context

In 1996, a number of major retailers and Greenpeace came together to form the PVC Retailers' Group. The Group was formed primarily in response to pressure on the retail industry to phase out the use of PVC in packaging and construction.

The Group commissioned a study from the National Centre for Business and Ecology (NCBE) "*...to review the evidence concerning the impact of the PVC on human health and the environment on the balance of probabilities.*"

NCBE reported in June 1997. The NCBE report stated that there was no overall scientific reason why retailers should not continue to use PVC. The conclusions of the report included the following:

> "*The study team concludes on balance that the careful manufacture, use, recycling and final disposal of PVC products to the highest standards can control the risks associated with the material to acceptable levels but will not completely eradicate them.*"

It recommended to the PVC Retailers' Group that the members should seek to ensure

> "*...the highest possible operational standards from the supply chain - manufacturers, processors and disposal operators...*", and that they should "*...keep the scientific evidence under regular review.*"

In 1998, the Group was reconstituted to include representatives of the UK PVC manufacturing companies (Hydro Polymers and EVC) under the chairmanship of Jonathon Porritt. The group was also renamed the *PVC Coordination Group.*

The newly constituted Group commissioned NCBE to prepare an *Environmental Charter for UK PVC Manufacturers* and an *Eco-efficiency Code of Practice for the Manufacture of PVC* for the industry, and these were agreed during 1999. As a contribution to evaluating the many questions raised concerning the long-term sustainability of the PVC industry, including those generated by the NCBE report, it was decided during 1999 to commission this independent investigation from The Natural Step office in the UK. The purpose of this analysis is to evaluate all factors relevant to the production, use and after-use of PVC from a sustainable development perspective, using the TNS framework.

The TNS framework is an international set of tools for tackling sustainable development, operated in the UK by *Forum for the Future* (charity number 1040519).

Method

This report is based on analysis of extensive documentation and structured interviews with manufacturers and other organisations involved in the PVC life cycle. The key documents used are summarised in the References section towards the end of this document. The manufacturers interviewed were Hydro Polymers and EVC. Discussions were also held with NCBE and with Greenpeace; a number of Environment Agency staff were also consulted by correspondence.

How is PVC Made?

PVC (polyvinyl chloride) is manufactured from two naturally occurring raw materials: oil and salt. The salt is processed in solution to produce chlorine, whilst the oil is "cracked" to produce ethylene. Ethylene and chlorine are then combined to produce ethylene dichloride (EDC), which is further processed to produce vinyl chloride monomer (VCM). The VCM is then polymerised to manufacture polyvinyl chloride (PVC), which occurs in the form of a white powder.

To become the versatile material, with its wide range of uses, PVC has to be combined with a wide range of additives. These include stabilisers, plasticisers, colouring agents, flame retardants. In the majority of applications (about 2/3 of the total weight of PVC produced), PVC is used in a rigid form. However, it can also be made pliable by the addition of plasticisers (most commonly phthalates).

It should be noted that the above processes do not normally all take place on the same site, therefore intermediate materials such as VCM and PVC are transferred between plants. Current world-wide production of PVC exceeds 20 million tonnes; European production is approximately 5.5 million tonnes.

Some Observations About PVC

- The benefits of PVC include excellent barrier properties to water and gases, mechanical strength combined with light weight, resistance to chemicals, inherent non-combustibility, electrical insulation properties, and versatility.

- Items and services for which PVC is widely used, such as pipes, windows, doors, packaging, medical applications, electrical insulation, will continue to be required to meet human needs. PVC will continue to be used as one of the options, often the preferred one, in many of these applications at least in the short-term future. Based on a report by the British Plastics Federation (1996 – see References), UK usage in 1994 included:

31% pipes/fittings	10% wire and cable	4% GP sheet and film
24% windows/doors	6% coated fabric/paper	4% automotive
14% packaging	6% wall/floor coverings	1% other

- PVC is a controversial material and has been attacked, principally by Greenpeace, who consider that it is "inherently unsustainable" and should be phased out as soon as possible (see References). Greenpeace's main concerns appear to be:

    - the release of toxic substances, especially organochlorines, associated with the manufacture, use and disposal of PVC products;

    - the implications of the many additives to PVC; and

    - the secondary difficulty in recycling and/or disposal of waste PVC products, and therefore their accumulation in nature.

- one of the risks associated with PVC is that it is a chlorinated organic compound from which the chlorine may recombine as a result of incautious disposal at the end-of-life of PVC-based products. Whilst other alternative materials might currently be no more or less sustainable, this is no insurance against addressing the ultimately unavoidable challenge of achieving sustainability.

- there is a limited amount of legislation against specific uses of PVC, or of additives to PVC, and a number of voluntary agreements restricting their use.

- there have been many life cycle analyses (LCAs) carried out upon various applications of PVC; probably more than for any other material. Inevitably they are of differing credibility. Some of the conclusions also appear to depend on whether the sponsor is an environmental pressure group or industry. However, the overall weight of them suggests that PVC is no more environmentally unacceptable/unsustainable than alternative materials, including "natural" ones, in the short to medium term.

- the recently-developed NCBE (National Centre for Business and Ecology) *Environmental Charter for UK PVC Manufacturers* and *Eco-efficiency Code of Practice for the Manufacture of PVC* being adopted by the UK PVC manufacturing industry marks an important incremental step on the road towards sustainability.

- sustainability considerations will increasingly impinge upon the industry (and others), challenging the acceptability of PVC products.

- the unsustainable nature of other products and processes does not in any way reduce the absolute requirement of the PVC industry to acknowledge its own unsustainability and to act to redress the position. There is therefore a need for the PVC industry to make progress towards sustainability, in parallel with moves towards sustainability throughout society. In order to achieve full sustainability for the PVC industry we need, as a minimum, sustainable feedstocks, renewable energy and sustainable transport. Whilst the PVC industry cannot deliver these in isolation, it can certainly support and influence sustainable development in other industries and in society as a whole, perhaps more so than other industries given its present profile in the media and with its users.

- the TNS approach reflects that all materials and processes must be considered within the overall framework of sustainability, and that issue-driven dogmas about "good" and "bad" materials are unhelpful. Indeed, these dogmas may potentially perpetuate the trend to make "knee-jerk" decisions that may be no more sustainable.

III. Analysis against the Four System Conditions

The PVC life cycle is examined through the lens of the four System Conditions of TNS in the following four sub-sections:

- III.(1) System Condition 1
- III.(2) System Condition 2
- III.(3) System Condition 3
- III.(4) System Condition 4

The TNS framework, and the derivation and relevance of the four System Conditions, are outlined in further detail in Appendix 1: About the Principles of The Natural Step. Collectively, these four System Conditions define the conditions that must be met in a fully sustainable future. As noted previously, the move to sustainability is inevitable, and they therefore signal pressures that will increase on the industry and which can be addressed either proactively (with associated competitive advantages) or reactively.

III.(1) System Condition 1

System Condition 1

Substances from the earth's crust must not systematically increase in nature.

This means that, in a sustainable society, fossil fuels, metals and other materials extracted from the Earth's crust are not released into nature at rates that exceed its capacity to absorb them. In practice, this means that they are not to be extracted at a faster pace than their slow redeposit and reintegration into the Earth's crust, or else they are to be used in a cyclic manner such that they do not accumulate in natural systems.

The principal substances from the earth's crust which are employed in the PVC industry are listed in Table 1, together with summaries of the options for dealing with them which are discussed subsequently and in greater detail in this section. These substances are mainly hydrocarbons which are used for feedstock, for energy and for plasticisers. Other materials covered include mercury, metal stabilisers and fillers. For each application, a summary is given of the way the System Condition is breached and how these breaches can be reduced or eliminated.

Table 1: Summary of System Condition 1 Analysis

Item	Nature of Breach/Note	Ways to Reduce/Eliminate
1.1 Hydrocarbon feedstock	Approximately 50% by mass of finished product. Linear resource use leads eventually to accumulation in nature	Use alternative feedstocks Recycle waste (in manufacturing process and of finished PVC products) Carbon sequestration
1.2 Mercury	Used in some chlorine plants	Being phased out
1.3 Stabilisers	Cadmium, lead, tin, zinc, etc., tend to accumulate in nature	Cadmium is being phased out Others to be replaced a.s.a.p. Recycle waste (in manufacturing process and of finished PVC products)
1.4 Plasticisers	Hydrocarbon-based phthalates (10%-46% by weight of flexible PVC) and other plasticisers	Seek alternative non-petrochemical based plasticisers Recycle waste (in manufacturing process and of finished PVC products)
1.5 Fillers	$CaCO_3$, for example in floor coverings	Recycle waste (in manufacturing process and of finished PVC products)
1.6 Energy for manufacture	Where fossil fuel-based, this adds to greenhouse gases	Investigate CHP plants and other means to improve efficiency of energy use and generation Use renewable energy
		Carbon sequestration
1.7 Energy for transport	Use of fossil energy in ship, rail, road transport emits greenhouse gases	Rationalise use Optimise mode Carbon sequestration

1.1 Feedstocks: Hydrocarbons

Hydrocarbon feedstocks (principally ethylene) comprise approximately 43% by weight of PVC. (This has to be compared with substantially higher percentages of hydrocarbons in other plastics; PVC is 57% chlorine by mass.) Under the conditions currently applying within the industry, and most critically to end-users of PVC products, this carbon essentially ends up as waste material deposited in landfill, or else is incinerated. This is a clear breach of System Condition 1.

The distribution of hydrocarbons is understood to be approximately 2:1 between feedstocks and fossil fuel usage in the manufacturing process. There is no consensus about the amount of fossil carbon reserves that can be used in balance with the planet's capacity to reintegrate them into the earth's crust. Neither is it clear that, if an acceptable level of world-wide fossil carbon usage were to be identified, it would be allocated to the manufacture of PVC. It is therefore consistent with the Precautionary Principle to consider this carbon usage unsustainable.

Ways to Reduce or Eliminate the Breach

Ethylene is currently sourced from fossil fuel stocks via the petrochemical industry. Alternative feedstocks which will either reduce the dependence on fossil fuels, or replace them, will need to be developed. Options currently available include biomass, ethane, coal and possibly other sources.

- Biomass could potentially be sustainable, but its use of land and the farming methods employed to produce it will have implications with respect primarily to System Condition 3 (see later in this report). Before any firm recommendation could be made about the future utilisation of biomass, an independent and detailed LCA would need to be carried out and evaluated carefully through the sustainability framework of TNS. (No such study appears to have been completed to date.)

- EVC has patented a manufacturing process using ethane and is currently testing it on a large pilot plant in Europe. The company has stated that it is more energy-efficient than ethylene, and may offer other sustainability advantages (some of these advantages are discussed when considering EDC in the section dealing with System Condition 2). However, long-term, the source of the material is still fossil fuels and so the above considerations would also apply. Unless there was provision to "close the loop" on the whole life cycle (as outlined subsequently), this alternative feedstock must also be considered unsustainable.

- Coal does not appear to offer any advantage apart from its wide availability; it will breach many of the System Conditions.

The development of alternative feedstocks, and of alternative sources for these feedstocks, is considered an important area for further research.

In addition to alternative sources of feedstocks, substantial increases in the recycling of waste PVC products would go a long way towards increasing their sustainability. Not only would it reduce demand for virgin resources (which breach System Condition 1), but increased recycling would also contribute to reducing other System Condition breaches as outlined in this report. 60,000 tonnes of PVC is diverted from the waste stream in the UK and recycled (reported to the authors from an otherwise confidential British Plastics Federation document). About 30% of this is post-use recycling and around 70% of this material is recycled scrap from some fabrication processes). It should be stressed that this is material diverted from the waste stream, and does not include the large quantity of PVC which is reprocessed within production factories (PVC converters achieve over 95% material efficiency with their in-house operations). In total, about 10% of the PVC in the UK is recycled, however about 3% of the PVC in the UK is recycled post-use.

Possibilities for increasing substantially upon this tiny level of recycling are matters not only for the PVC industry but society as a whole, although the consequences of unsustainability should focus thinking by the industry on supporting the necessary initiatives and infrastructure. Other business sectors with high usage of PVC products (including the retail industry and especially in the packaging waste stream) also have a leadership role to play.

Even with all the above possible improvements, there will inevitably remain a net breach of System Condition 1 in respect of hydrocarbon-based, non-renewable feedstocks, at least in the medium term. As an interim measure, the industry should consider investing in compensatory carbon sequestration[2] schemes to offset this breach.

Question 1(a): Is it possible for the industry to commit itself long-term to carbon-neutrality, including the use of renewable feedstocks, "closing the loop" on remanufacture[2], energy efficiency, and compensatory carbon sequestration schemes[3]?

1.2 Mercury

Mercury was used as one of the electrodes in many plants for the production of chlorine. The amount of mercury entering waste streams at these plants has been much reduced in recent years.

The chemicals industry itself has recognised the need to stop dispersing mercury into the biosphere, as well as recognising the compulsion not to do so through various pieces of legislation such as the EC Dangerous Substances Directive. There is also an OSPAR recommendation that mercury should not be used for this and many other purposes by 2010. Consequently, the chemical industry has been able to develop processes which eliminate the use of mercury. Mercury-based plants are being phased out at present and no new ones are being built.

The above change illustrates the type of shift in technology and thinking implicit in the application of the principles of The Natural Step, and exemplifies the legal, reputation and economic drivers for making changes that could reasonably have been foreseen and subject to a proactive sustainable development strategy rather than a reactive one.

Chlorine is now made predominantly by the diaphragm process, which is reported to have much lower pollution levels and which results in no mercury emissions. However, these diaphragms are made of asbestos. Though no published studies of the implications of using asbestos for this purpose have been seen, concerns have been expressed about this technology. Other processes for chlorine production (i.e. membrane methods) also eliminate use of mercury. The membrane technique remains the BAT (Best Available Technology) simply on the basis that it does not involve mercury, and not because any study has been undertaken on its inherent sustainability.

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[2] We shall return to the theme of closed loop manufacture again; further details can be found in Appendix 2 : Closed Loop Manufacture

[3] "Carbon sequestration" is the process of immobilising carbon emissions that might otherwise accumulate in the atmosphere with unpredictable consequences. The most common method is to plant trees in long-term plantations, relying on the photosynthetic activity of these trees to "lock up" carbon dioxide into the solid form of wood. Other technical approaches are being explored and developed.

A separate study founded on TNS principles of sustainability would be useful to explore the most sustainable forms of producing chlorine, and to address the wider questions raised by organochlorine chemistry.

1.3 Stabilisers

PVC is thermally unstable and cannot be formed into products without the use of heat stabilisers. Stabilisers also enable sophisticated processing of PVC. A wide range of stabilisers is used in finished PVC, and these always contain metallic compounds together with various organic compounds. The stabiliser used largely depends on the final application. Many of the metals used in the form of metal-based salts or soaps as PVC stabilisers are heavy metals, including cadmium, lead, tin, antimony and zinc compounds. Calcium, usually in the form of calcium stearate, is also used, as are barium-zinc and calcium-zinc for different applications. The use of cadmium is of particular concern and has not yet been fully phased out. Metal-based stabilisers are normally present in quantities up to 2% by weight of the PVC, and they are physically bonded into the PVC matrix and cannot be easily removed.

As a contribution towards sustainability, stabilisers do allow PVC to be used in durable long-life applications. However, the heavy metals used are not only toxic (most are listed in the EC Dangerous Substances Directive), but they will tend to disperse into nature. This can occur during production, manufacture (i.e. in wastes from processing) and finishing, during product life (by both chemical and physical breakdown) and also at end-of-life in landfill, incinerator gases and ash, etc. Use of these materials without comprehensive recycling therefore constitutes a breach of System Condition 1. Consideration of the implications of all of the exhaustive list of metallic compounds used as stabilisers is beyond the scope of this report. However, the general principles applied to the selected stabilisers apply equally.

Lead stabilisers in Europe comprise some 60% of the PVC market, and this is primarily because lead is cheap when compared to alternatives (mainly calcium stearate and zinc salts). Lead is a known toxin, and remains a cause of concern. The PVC industry disputes the need to substitute lead, based on a risk assessment perspective, since it appears to be relatively inert when deposited in landfill, but is anyhow considering measures to phase out lead in the medium term. However, putting waste into landfill is both wasteful of resources (as discussed in the later consideration of System Condition 4) and also a linear resource use that does not effectively lock it away from the rest of the biosphere over geological time scales. It merely detains it. For this reason, putting lead-containing waste into landfill – or worse still through an incinerator – breaches System Condition 1, and should be phased out as quickly as practicable.

Whilst small quantities of zinc are required for the human body, excessive levels may be problematic. Zinc salts can be used as alternatives to lead stabilisers and are used in combination with calcium salts in certain applications. However, zinc has also been listed on the EC Dangerous Substances Directive, therefore there are related concerns which may also apply for tin (see concerns raised in the section of this report analysing System Condition 2 impacts). It would be naïve to assume that other materials are more sustainable without further detailed study in the context of the overall PVC life cycle.

The PVC industry makes the valid point that metal compounds are present in ceramics and glass at far higher concentrations than in PVC formulations although, at present, nobody questions this application or suggests that ceramic plates are unsustainable. (Industry representatives note that the official Swedish test institute conducted tests to see how lead migration from a PVC pipe would compare to the limits set down in the EU Ceramics Directive – which covers migration limits for food contact ceramics – and that their results show it is just as safe to eat meals off a lead-stabilised PVC pipe as it is to eat them off a ceramic plate.) To avoid getting lost in technical detail, it is important to reiterate that the breach of this System Condition relates to the capacity for metals systematically to accumulate in nature, a sustainability challenge which the PVC industry – as eventually all sectors of business will – must face across the material's complete life cycle.

Ways to Reduce or Eliminate the Breach

It is understood that recycling of wastes back into the process is carried out extensively within the factory. However, the problem on System Condition 1 compliance seems to rest largely with the linear use of finished products. As a general principle, where additives present a problem that inhibits recycling, they should be eliminated, or else the product becomes the problem. The following specific examples illustrate this point.

Cadmium has not yet been phased out by all PVC companies. Owing to its high toxicity and rarity in nature, as well as various regulatory requirements to eliminate its use and widespread public concern, it should be phased out as quickly as is possible. A further inducement to eliminate cadmium from PVC immediately is the difficulties that it presents to the acceptability of recycled PVC. There may be a case to derogate the presence of cadmium in certain products made from recycled PVC in the short term if this might otherwise encourage the continued linear use of resources. (For further details of this, refer to Appendix 2: Closed Loop Manufacture) This judgement would have to be made as part of a wider life-cycle sustainability analysis based on TNS principles.

Lead also presents problems, and it is suggested that the industry should phase it out rapidly and ahead of any impending regulations so to do. It should be transmaterialised[4] with alternative materials which ease recycling and which are less scarce (and consequently less harmful) in nature.

In order to reduce the System Condition 1 breaches of all metal-based stabilisers, increased recycling of waste products, which would include the stabilisers, is again recommended in the short term together with transmaterialisation. A helpful approach to transmaterialisation of metals consistent with steps towards complying with TNS principles is provided in a paper by Azar, Holmberg and Lindgren (1996 – see References). Longer term, the development of a closed-loop manufacturing system (cyclic reuse of materials, rather than the linear mine-use-dispose ethos) is strongly advocated as a major step towards sustainability (see Appendix 2: Closed Loop Manufacturing, together with alternative safer and more readily remanufactured additives.

1.4 Plasticisers

About 2/3 of PVC products in use in the UK are rigid. Plasticisers are added to the remaining 1/3 of products in order to make them flexible. The major plasticisers used are phthalates, and their use in PVC accounts for some 95% of the UK market. Various alternative plasticisers including citrates, adipates, benzoates and trimellitates are also used for some applications. Long-chain chlorinated paraffins have other applications, however approximately 75% of the chlorinated paraffins manufactured are utilised as PVC plasticisers.

[4] "Transmaterialisation" means the substitution of materials in current use by those that pose a lower risk. This may be because they present a smaller obstacle to recycling or are less toxic or legally problematic. Transmaterialisation can be a useful step towards sustainability when the ultimate solution of "dematerialisation" - achieving the same technical functions with no or less material - is not immediately practicable.

Solid polymeric substances, such as EVA (ethyl vinyl acetate), which have discrete applications such as infilms and adhesives, are also used as plasticisers for some specific PVC applications. Plasticisers can comprise from 10% to 46% by weight of flexible PVC products[5]. Phthalates and other plasticisers are hydrocarbon-based. Although the principal concerns about phthalates are covered by System Condition 2, plasticisers also constitute a System Condition 1 breach similar to that of the main hydrocarbon feedstock albeit on a slightly smaller scale, because these hydrocarbons are presently sourced mainly from fossil reserves.

Ways to Reduce or Eliminate the Breach

Recycling of waste products, and working towards closed loops, will again contribute substantially towards sustainable development. The industry should also seek alternative non-petroleum based plasticisers.

Question 1(b): Is it possible for the industry to commit itself long term to ensuring stabilisers are only employed in a closed-loop system, and that alternative renewable sources are used for plasticisers?

1.5 Fillers

These comprise materials such as calcium carbonate, which are used in PVC-based floor coverings (up to 50% by weight), window frames, electrical cables and similar products. Materials used as fillers are generally widely available and abundant, and are not believed to have any significant toxic effects during their manufacture, use or disposal. They do however constitute a technical breach of System Condition 1.

Whilst the System Condition 1 breach may itself have a relatively minor significance, the potential for fillers to inhibit the recycling of PVC products is of far greater concern. The UK PVC manufacturing industry do not see this as a problem in present formulations, although acknowledging that awareness about all additives in the formulation is essential to ensure that obstacles or disincentives to recycling are avoided. However, the fact that PVC formulations can accommodate very high filler quantities means that there is far greater scope for recycling with PVC than with other comparable materials (most other thermoplastics could not tolerate such high levels of impurity in their formulation). There are therefore both risks and opportunities to be managed by the PVC industry as a component of its sustainable development.

Ways to Reduce or Eliminate the Breach

A study is suggested taking into account the impact of the fillers currently employed on the sustainability of PVC products and in particular the feasibility of recycling them. Alternative fillers, which could make this technically easier, need to be assessed. At a basic minimum, there should be clear methods available for identifying the filler (and other materials) contained in end-of-life PVC products to aid reuse and/or recycling.

Question 1(c): Is it possible for the industry to commit itself long term to ensuring that all fillers are amenable to the recycling of PVC products?

[5] Greenpeace claim to have analysed a medical product with 80% phthalate content, but the PVC manufacturing industry disputes this figure.

1.6 Energy Used in Manufacture and Processing

Oil and natural gas are used directly in PVC manufacturing and processing plants, and electricity (which is mainly generated from fossil fuels) is also widely purchased from electricity generating companies. The principal impacts of this energy consumption are in the direct or indirect generation of greenhouse gases.

Climate change resulting inter alia from the generation of greenhouse gases is possibly the major environmental challenge facing the world today. Every sector of society will have to contribute to a major reduction in the consumption of hydrocarbon fuels and progressively switch to the use of more efficient systems and the employment of renewable sources of energy. This reduction is likely to be compulsory in the foreseeable future, and also to be the subject of economic instruments. The introduction and likely progressive toughening of "carbon taxes" mooted by the UK Government clearly demonstrates the urgency for the industry in formulating medium- to long-term plans to reduce radically dependence on fossil hydrocarbons.

It is acknowledged that there will continue to be some use of hydrocarbons but, in a sustainable future, the amount permitted can only be a small fraction of that currently consumed. (This may, for instance, be in the region of 20% of today's global level.) There is no assurance that this allocation will go to developed countries. This places significant demands on all sectors of society including the PVC industry, and there is no presumption that any sector will have priority over this fraction. In determining how it will achieve this reduction, the PVC industry will need to carry out detailed analysis to determine how this is best achieved; whether by major reductions/elimination of hydrocarbon use for energy generation, by substitute feed stocks, by less energy-intensive processes, or by other means.

PVC is however the least energy-intensive of all the thermoplastics, and uses only a quarter of the energy required for glass. Despite a higher starting energy-efficiency, the above challenge is real and present.

Ways to Reduce or Eliminate the Breach

This is most effectively addressed by energy efficiency, offering the lowest-cost initial approach to reducing the amount of fossil fuel use, and then by replacing the use of fossil fuels by renewable sources. Installation of additional efficient local Combined Heat and Power (CHP) plants can substantially improve energy efficiency[6].

Greater use of renewable energy for generation of electricity could also make a major contribution (including for example buying into regional "green energy" schemes). The industry needs to assess as a matter of urgency the ways in which it will pursue these options as a contribution towards a sustainable energy policy: current energy use patterns are not a long-term option.

Other methods for improving energy efficiency should also be pursued vigorously within the industry. For example the use of novel energy-efficient refrigeration systems would be a further contribution. Rationalisation of the industry to have fewer large plants, developed to be closer to feedstock sources and final markets, is also an option that should be evaluated including social and economic implications.

[6] Greenpeace have expressed concern that CHP should not be seen as an inducement to burn more waste PVC on site, and representatives of the PVC manufacturing industry have indicated that CHP will not be used for this purpose.

Finally, carbon sequestration schemes are likely to be essential, at least in the medium term, if a carbon balance is to be achieved by the industry. (These substantial concerns have already been included in Question 1(a).)

1.7 Energy for Transport

The industry makes use of ship, road and rail for the transport of feedstock, products and waste materials. This also generates greenhouse gases and uses fossil fuels from the earth's crust.

Ways to Reduce or Eliminate the Breach

The two principal ways of reducing this breach are reducing the amount of transport required and improving the efficiency of its use.

Rationalisation of the plant location and feedstock sources, as noted above, can also contribute significantly to transport efficiency. All such measures have to be addressed within a wider framework of sustainability rather than tackled on a single-issue basis, since substantive increases in the quantity of PVC recycling might best be effected in more smaller plants.

Whatever the plant strategy, improved utilisation of transport should be given high priority as a means for making a significant contribution to energy saving. Selection of the optimum mode of transport may also make a significant contribution to sustainable development.

Question 1(d): Is it possible for the industry to commit long-term to becoming "carbon neutral[7]" in respect of the hydrocarbons consumed for energy and transport?

[7] Where the overall carbon dioxide emissions of an industry or activity, both directly and indirectly (for example from power stations serving a factory), derive from fossil fuel reserves, the net input of carbon dioxide and other gases into the atmosphere contributes to climate change. For this reason, the UK Government is currently exploring some form of carbon (or energy) taxation. The term "carbon neutral" defines the concept of offsetting the overall emission of carbon.

III.(2) System Condition 2

System Condition 2

Substances produced by society must not systematically increase in nature.

This means that, in a sustainable society, chemical substances are not produced at a faster pace than they can be broken down by and reintegrated into natural cycles. In practice, this means that they must not be released into nature at a faster pace than their slow breakdown and reintegration into nature, otherwise they might build up in concentration with unforeseen results. This can be achieved by elimination of the most persistent and bioaccumlative substances that can cause severe and unpredictable effects upon nature, or in some cases by the full "closed loop" use of these substances by society.

The principal chemical substances produced by society employed in the PVC industry are listed in Table 2, together with summaries of the options for dealing with them which are discussed subsequently and in greater detail in this section. These substances comprise the PVC product itself and its additives, intermediates and by-products of manufacture and disposal, and other substances used in manufacturing processes. For each application, a summary is given of the way the System Condition is breached and how these breaches can be reduced or eliminated.

A fundamental difficulty in assessing the specific risks from additives to PVC is the very large variety of chemical compounds used and their precise formulation which, for reasons of industrial confidentiality, is not known in detail. However, the broad categories of additives are well documented, and the general risks are clear. Although we may treat landfill as if it were "forever", waste is not rendered completely inert nor locked away in perpetuity from the biosphere. Therefore, entropy (the second law of thermodynamics) inevitably means that additives of all kinds (and their derivatives) will tend to leach out and accumulate in nature in the longer term. Essentially, unless a closed-loop system of remanufacture for PVC is progressively brought in, PVC wastes will ultimately be a source of potentially toxic releases into nature, the longer-term impacts of which are largely unforeseeable.

Table 2: Summary of System Condition 2 Analysis

Item	Nature of Breach/Note	Ways to Reduce/Eliminate
2.1 PVC products	A persistent man-made product which accumulates in landfill and in nature	Increase recycling for reprocessing Long-term closed loop manufacturing
2.2 Chlorine feedstock	From salt deposits	Alternative chlorine sources (e.g. desalination plants) Recycle waste (in manufacturing process and of finished PVC products)
2.3 Dioxins & Furans	Highly toxic Minor direct amounts to atmosphere from PVC manufacturing Inputs to all media from incineration end-of-life. Emissions from transport	Maintain and improve best practice at all plants Alternative manufacturing processes Eliminate emissions long term

2.4 VCM	An intermediate product, which is also stored and transported. It is toxic, but breaks down quite rapidly into HCl/CO_2	Reduce fugitive emissions Rationalise plants to reduce transport Ensure emissions do not result in increases in concentration in nature
2.5 EDC	A "transient" product in manufacturing process. It is also toxic	Ensure emissions do not result in increases in concentration in nature
2.6 Other organochlorines	Toxic emissions, by-products of manufacturing, and potential breakdown products in use and post-disposal	Ensure emissions do not result in increases in concentration in nature
2.7 Refrigerants and Fire Fighting Chemicals	These are currently mainly HCFCs, which are global warming and ozone-depleting gases	Convert to non-ozone depleting or low-energy systems
2.8 Plasticisers	Mainly phthalates, but also other potentially persistent potentially bioaccumulative substances. Phthalates are implicated in endocrine-disruption, accumulation in invertebrates and toxic effects in rats, and leaching does occur during product life and post-disposal	Replace by non toxic alternatives Recycle wastes
2.9 Stabilisers	Many contain heavy metals (often present as stearates, etc)	Recycle wastes Replace by non-toxic alternatives

2.1 PVC Products

PVC is a man-made material most of which currently ends up in landfill. Whilst PVC products are generally inert, physical and chemical breakdown in use, leaching or migration of additives, and accumulation in waste streams all result in loadings into the environment over the longer term. This is a breach of System Condition 2 (that is they will accumulate in nature).

The generation of organochlorine substances through incineration, either controlled or uncontrolled, is also a substantive cause for concern where these are not fully removed from emissions to air, water and/or land.

Ways to Reduce or Eliminate the Breach

The linear use of resources – *mine-use-dispose* – is one of the biggest obstacles to sustainability. Increasingly clean and efficient production processes are laudable, but if the products are merely landfilled or incinerated at end-of-life, this is not only a wastage of resources (see System Condition 4) but also results in the accumulation of wastes in nature. To overcome this primary linear usage and a growing quantity of waste and breakdown products (often unknown), end-of-life products should be reused or recycled. A more detailed consideration is given to recycling and closed-loop manufacture in Appendix 2: Closed Loop Manufacture. Additives in finished products, addressed elsewhere in this report, could compromise the possibility of recycling. Although the UK PVC industry do not perceive barriers to recycling in present formulations, this possibility presents both a risk and an opportunity to be managed as a component of sustainable development. Were obstacles to be erected to efficient recycling, this would decrease substantially the overall sustainability of the material. In practice, only a tiny proportion (perhaps no more than 3% of PVC products post-use) are recycled today in the UK, so there is scope for substantial progress towards sustainable development, given adequate attention to the problem. It is in the long-term interests of both PVC manufacturers, and other businesses that rely heavily upon PVC products, to take ownership of these problems and address the development of a more fully sustainable PVC life cycle as a business priority.

The question has to be posed as to whether it is feasible to develop a closed system for PVC. This is discussed in several places elsewhere, and also in detail in Appendix 2: Closed Loop Manufacture.

Question 2(a): Is it possible for the industry to state as a long-term objective the intention of having a "closed loop" system for PVC waste?

2.2 Chlorine Feedstock

Chlorine is derived from salt deposits. Caustic soda (sodium hydroxide) and hydrogen gas, which have applications elsewhere, are co-products of this manufacturing process. PVC manufacture accounts for 30% of world chlorine production. The remaining 70% is split between other plastics, pulp and paper (now being phased out), pharmaceutical and pesticide manufacture, water purification, bleaches and solvents, and other uses.

Some might consider the usage of salt itself to be insignificant compared with other breaches, given its wide and easy availability, although this is a qualitative judgement. However, the chlorine remains locked into the PVC when it is deposited in landfill, and this linear flow of resources "from mine-to-waste heap", or to incinerator, is a breach of System Condition 2 as it has the potential for chlorinated compounds to accumulate in nature.

Of far greater concern in respect of chlorine is the existence of organochlorine compounds associated with PVC and its breakdown products. This is explored in section 2.6.

Ways to Reduce or Eliminate the Breach

The breach of System Condition 2 relates to the accumulation in nature of waste chlorine and of other substances produced during its manufacture. Alternative sources of chlorine (for example, from desalination plants) may provide less polluting means of extraction (as discussed in section 1.2 on Mercury), but may not address the fate of the chlorine at the end-of life of PVC products. Any technical improvement on the breach of this System Condition, subject to future LCA scrutiny, would be welcome. In any event, it appears likely from this analysis that the implications "downstream" of the chlorinated wastes is of greater concern than the source of chlorine itself.

"Closing the loop" across the whole PVC life cycle, and thereby minimising waste post-use, would be a major contribution towards eventual sustainability. This is discussed later, and in more detail in Appendix 2: Closed Loop Manufacture.

2.3 Dioxins and Furans

The production of dioxins and furans during manufacture and waste incineration has been among the most controversial aspects of the PVC industry. Dioxins are one of the most toxic group of substances known, and are also extremely persistent in nature.

There is now considerable evidence that the amount of dioxin released from the PVC industry itself is minor, and at levels that the industry consider to be "insignificant", compared with many other industries and processes. Nevertheless, any contribution to increasing levels of persistent and bioaccumulative substances in nature is not sustainable. Public and legislative pressure are two further factors determining that this issue must be addressed within the wider context of sustainable development.

There is no evidence that virgin PVC resin now contains any dioxins, and this is supported by analytical studies (for example Wagenaar et al, 1998 – see References).

The uncontrolled burning of PVC products, or the non-recovery of chlorine from controlled incineration, is also of substantial concern. Until better measures exist to facilitate the reuse of PVC, this source of dioxins is likely to remain and to blight the reputation of the manufacturers of the plastic.

Other sources of dioxins include transport, and the 1995 HMIP report (see References) on dioxin in the UK indicates that coke-burning may be a significant source where it is used as a fossil fuel in industrial processes.

Ways to Reduce or Eliminate the Breach

Strict standards have been introduced into the industry, which have been successful in controlling dioxin releases to what the industry claims to be "insignificant" levels. Dioxin by-products consisting of "light" and "heavy" fractions of organic chlorine compounds are formed during the manufacturing process, and these contain small amounts of dioxin. However, they are now incinerated with the recovery of hydrochloric acid and the industry claim to have fully eliminated dioxins deriving from incinerator ash. Maintenance of the high standards is essential to preserve this situation. Long term, dioxins from this source must be fully eliminated if the industry is to be considered sustainable.

Dioxin emissions from transport and fossil fuels must also be addressed through transport and energy-efficiency schemes, and the detailed examination of all processes is likely to be problematic, although it is recognised that this is a problem that is society-wide and not specific to PVC manufacturers and users.

Tackling the emission of dioxins from end-of-life products can only be achieved through more detailed work on "closing the loop" on PVC as advocated throughout this report. Greenpeace believe PVC to be inherently unsustainable precisely because if chlorine goes into a process then chlorine must come out and, where the loop is not fully closed or otherwise controlled, dioxins and other organochlorine substances are the likely products of incautious disposal. The PVC industry refutes this claim, but the principle of eliminating problematic emissions across the whole life cycle of the plastic remains a priority to be addressed.

2.4 VCM (Vinyl Chloride Monomer)

VCM is an intermediate product formed during the manufacturing process for PVC. In the early days of the industry, levels of VCM released within manufacturing plants were high enough to have caused cancers amongst plant operatives. Processes have subsequently been changed such that the emissions are currently at a level that is well below any predicted trigger level for adverse health effects.

During normal operation the emissions are no longer hazardous to operatives or neighbours of the plant; however there is always the possibility of a substantial release arising from an accident within a plant or during the inter-plant transportation process. VCM may be stored within the plant where it is manufactured for subsequent processing, or it may be transported to another plant which does not have a VCM process. Although it is toxic, this is essentially a local problem as VCM degrades relatively quickly (it has a half-life of about 14 hours) to hydrochloric acid and carbon dioxide, so it does not persist in nature as VCM. However, hydrochloric acid can of course be extremely damaging to the environment.

Ways to Reduce or Eliminate the Breach

The ultimate goal of sustainability will be met when no VCM or breakdown products (which may potentially include persistent and potentially bioaccumulative substances) accumulate in nature. The means for addressing this might include further measures to eliminate all fugitive or accidental emissions within plants, rationalisation of locations to reduce inter-plant transport, tighter procedures to reduce further the risk of accidental releases both within plants and during transport, or production methods eliminating the formation of VCM.

The breach of System Condition 2 arises where the substance, or its breakdown products (across the whole life cycle and including post-disposal of PVC products), accumulate in nature. Elimination of emissions causing such an accumulation is a fundamental sustainability challenge for PVC.

2.5 EDC (Ethylene Dichloride)

EDC is an intermediate product in the manufacturing process. Some EDC is stored within the plant. It is toxic, and steps to minimise its release to safe levels have been introduced in the industry. It breaks down to hydrochloric acid and carbon dioxide.

Ways to Reduce or Eliminate the Breach

The presence in nature of EDC, or of its breakdown products, would be a breach of System Condition 2 for reasons provided for VCM. Rigorous standards of containment are essential to minimise possible breaches, consistent with the approaches noted above for VCM and dioxins.

As noted in considering petrochemical feedstocks in the section dealing with System Condition 1, the alternative PVC manufacturing route using ethane is more energy efficient than ethylene and may offer other sustainability advantages. One of them is that there is no EDC production in the process. The overall contribution to sustainability by this alternative manufacturing route across the full life cycle would have to be explored in a separate study in order to make a judgement about its relative strengths and weaknesses.

Question 2(b): Is it possible for the industry to commit long term to eliminating emissions of VCM and EDC?

2.6 Other Organochlorines

Concern has been expressed about the generation of other organochlorine compounds arising directly from PVC manufacturing, and as a consequence of disposal of PVC products. This has largely been outlined in the preceding consideration of dioxins. This collateral production of organochlorines was one of the key points made in the recent Greenpeace letter to the PVC Coordination Group (1999, see References). Problematic organochlorines of concern to Greenpeace include fugitive emissions from plants of vinyl chloride monomer and ethylene dichloride (addressed in 2.4 & 2.5), and also filters and incinerator ash contaminated with dioxins. As noted above, the industry claim to have eliminated dioxins from these sources.

Greenpeace also claims that incineration actually increases the amount of toxic waste because of the addition of salts to neutralise the hydrochloric acid generated by incineration, although the industry counter this by noting that chlorine recovery is undertaken.

Ways to Reduce or Eliminate the Breach

As a general point, the same controls should be exercised in respect of other organochlorine compounds as for dioxins as summarised above. Issues of specific concern should clearly be explored consistent with this approach.

Question 2(c): Is it possible for the industry to state as a long-term objective their intention of eliminating emissions to all media of dioxins (and other organochlorines)?

2.7 Refrigerants and Fire Fighting Chemicals

The primary usage of refrigeration in PVC manufacture is the liquefaction of VCM gas, which could also be achieved by compression. Balancing risks to the environment with those of safety, the PVC manufacturing industry favour cooling. HCFCs are the refrigerants principally used during the manufacturing process. They are less ozone-depleting than CFCs formerly used, but they are still significant ozone-depleting and global warming gases.

Various fire-fighting chemicals are used in the manufacturing process. Although the fire-fighting chemicals have not been identified, many are known ozone-depleting gases and thereby account for substantial System Condition 2 breaches.

The goal of full sustainability can only be met when there is no breach of System Condition 2 through the release of ozone-depleting, global-warming or other persistent and unnatural substances into nature.

Ways to Reduce or Eliminate the Breach

Conversion of the refrigeration plants to non-ozone-depleting substances is technically possible. Establishing targets for eliminating fugitive emissions of HCFCs during the transition period should be introduced. New, lower energy refrigeration processes are becoming available and should be assessed. There may be other ways of providing cooling services that are not currently in use by the industry (for example, Electrolux is exploring more sustainable methods for providing cooling services using the TNS framework as its strategic tool). Alternatively, manufacturing processes that do not require refrigeration may have to be investigated.

Implications for retailers using refrigeration are similar, as is the need to balance environmental and safety considerations in the short term. Long-term, fully sustainable solutions will be environmentally benign and risk-free.

Question 2(d): Is it possible for the industry to state their long-term commitment to eliminating ozone-depleting refrigeration gases and fire fighting chemicals?

Question 2(e): Should the industry investigate processes that reduce and ultimately eliminate the need for refrigeration (also producing energy-intensity benefits)?

2.8 Plasticisers

Many plasticisers are in use in PVC products, and the basic types have already been detailed in the section dealing with System Condition 1. Around 30% of PVC products contain plasticisers in proportions ranging from 10% to 46% of the final product. The main concerns about these products are their possible carcinogenic and other biological effects.

Phthalates are the most common plasticisers in PVC. They are recognised as being readily biodegradable under aerobic conditions, but can persist in certain environments (including anaerobic river sediments) and they do bio-accumulate in invertebrates. Many phthalates have been implicated in endocrine disruption (including oestrogenic and anti-androgenic effects), as well as being directly toxic under certain conditions. Studies indicate that some phthalates can cause cancer and genetic damage in rats in high doses. Although IARC/WHO now accept that the most commonly-used phthalates are not carcinogenic to humans, and the PVC industry too maintain that the data support this view, there is still argument in the scientific literature. As yet, there is no clear consensus about the details of how these chemicals interact with nature and humans, and phthalates are currently undergoing environmental risk assessment as part of the European Union's strategy on chemicals.

Concern has been expressed about plasticised PVC products in direct contact with foodstuffs and also in children's toys, teething rings, etc. Scientific studies of these matters continue. The industry has stopped using PVC in some applications and the European Union has introduced some legislation against the use of such products for toys to be chewed or sucked by children. The European Toy Manufacturers Association has also announced a ban on the sale of PVC teething rings, and other "suckable" toys, containing phthalates. Further understanding about the potential for endocrine disruption will soon be published as part of the EU's ongoing environmental risk assessment on phthalates.

It seems likely that pressure will continue for the elimination in the longer term of all potentially endocrine-disrupting substances. Whether for reasons of public concern, legislation or supply chain pressures, this demonstrates the TNS metaphor of "hitting the walls of the funnel", eventually forcing more sustainable practice on business. It also demonstrates the wisdom of being proactive in addressing sustainable development as a strategic business challenge, rather than retrospectively, defensively, and at greater cost.

From a System Condition 2 perspective, any substance - including its breakdown products - that has the potential to be toxic to or accumulate in nature must be viewed as of concern regardless of currently-known toxic effects. Where there is no clear consensus about the details of how these chemicals interact with nature and humans, the System Condition implies management of all releases across the whole product life cycle (including beyond end-of-life) such that they, and their breakdown products, can be broken down and reintegrated by natural processes without any accumulation or adverse effects. Given that appropriate levels for these releases are not yet known, the Precautionary Principle would suggest that incautious use and emission are not sustainable. These same principles, applied here to thinking about the better-known phthalates, also apply to other plasticisers.

Ways to Reduce or Eliminate the Breach

These substantive concerns indicate that the industry should take seriously the need to review the present range of plasticisers, and not just the currently more contentious family of phthalates. It is also necessary for the industry to be aware that pressure from legislation and public concerns, now and in a future with increasing constraints, can have severe impacts on its economic viability if steps have not been taken in advance to deal with such concerns.

If it could be demonstrated by an appropriate analysis, for example using The Natural Step framework, that alternative materials were genuinely more sustainable, the new materials could reduce the breaches. In the absence of such an analysis, it would be reactionary to assume automatically that alternatives to a known or suspected problematic substance were any safer. Recycling of waste at end-of-life, and at all other points in the life cycle so as to prevent the leaching of substances from PVC products and recombination with other substances in the environment, would also be of major significance in the interim. This is considered in greater detail in Appendix 2: Closed Loop Manufacture.

Question 2(f): Is it possible for the industry to state that it is their long term intention to eliminate the use of endocrine-disrupting substances, whether as plasticisers or other additives, where there is the potential for them to accumulate in nature?

2.9 Stabilisers

As already noted in the consideration of stabilisers under System Condition 1, a wide range of metal soaps or salts is used in PVC products as stabilisers. The metals themselves predominantly contravene System Condition 1, although the organometallic compounds used as stabilisers and also the complex compounds that they form in landfill and elsewhere constitute a breach of System Condition 2. In a sustainable future, all such organometals that are persistent and potentially bio-accumulative would be phased out or used only in ways that did not result in their accumulation in nature.

Organo-tin compounds are commonly present in clear rigid PVC applications such as in sheeting, packaging film and bottles. The tin is commonly present in mixtures of di-alkyl and mono-alkyl-tin, such as for example dioctyl tin or octyl thiotins. These forms of tin are approved for food contact. Tri-alkyl tin compounds, such as tributyl tin (TBT) which is commonly used as an anti-fouling agent in shipping and has known endocrine-disrupting and other toxic effects, are not used in PVC. All other metallic compounds used as stabilisers will have their own detailed considerations, but tin is used here as an example.

From a System Condition 2 perspective, if the substance does not accumulate in nature, nor evidence damaging properties, it may be a sustainable option. This assessment would have to be made across the whole life cycle.

Ways to Reduce or Eliminate the Breach

"Closing the loop" to prevent linear usage of metal-containing PVC products end-of-life has already been addressed elsewhere, but is fundamental to eliminating accumulation in nature. Where accumulation occurs and adverse effects are observed, transmaterialising to a safer compound may be a viable alternative short-term whilst long-term sustainable solutions are sought.

III.(3) System Condition 3

System Condition 3

The physical basis for the productivity and diversity of nature must not systematically be diminished.

This means that, in a sustainable society, the productive surfaces of nature, including their biological diversity and the processes that ecosystems perform, are not diminished in quality or quantity. We must not harvest more from nature than can be recreated and renewed, nor seriously compromise the processes performed by natural systems.

The principal ways in which the earth's productivity and diversity are diminished by the PVC industry are listed in Table 3, together with summaries of the options for dealing with them which are discussed subsequently and in greater detail in this section. These activities include those associated with the extraction of resources, transport and waste disposal, and the physical footprint of manufacturing works. For each, a summary is given of the way the System Condition is breached and how these breaches can be reduced or eliminated.

Table 3: Summary of System Condition 3 Analysis

Item	Nature of Breach/Note	Ways to Reduce/Eliminate
3.1 Raw Materials	Oil production/refining destroys habitats and consumes land area Energy use also has impacts on habitat and land area	Reduce dependence on oil Evaluate impact of biomass production Consider energy implications
3.2 Manufacturing Plants	Occupy large areas of land	Rationalise plants Encourage ecosystems at facilities Mitigate new development
3.3 Transport	All transport infrastructure causes habitat	Optimise transport mode loss and disturbs ecosystem processes
3.4 Waste Disposal	Areas of landfill taken by waste products	Reduce waste Increase recycling Head towards "closed loop" manufacturing
3.5 Water Use	Substantial quantities used in manufacture	Improve water efficiency Recycle water in industrial processes
3.6 Mining of Stabilisers, etc	Mines destroy habitats and disturb the water table	Reduce/substitute fillers

3.1 Raw Materials

The PVC industry currently uses substantial quantities of hydrocarbon for feedstock and for energy generation. The production, refining and transportation processes for these hydrocarbons inevitably damage or destroy habitats. If a future PVC industry continues to use hydrocarbons on the same scale, this element of unsustainability will persist.

Ways to Reduce or Eliminate the Breach

As noted under System Condition 1, alternative feedstocks and energy use with a lower or no fossil fuel content have been proposed. Some alternatives would appear to offer an opportunity for a more sustainable source of feedstock. However, these all require further detailed evaluation. For example, there is a possible negative impact of the land take and biodiversity loss from monoculture farming for biomass feedstock, were current intensive farming methods to be followed, and possible transport implications if the biomass sources are distant from the plants.

Question 3(a): Is it possible for the industry to state as a long-term commitment a switch to renewable and sustainably-produced feedstocks?

3.2 Manufacturing Plants

PVC manufacturing and processing plants, and other chemical plants, occupy land. In the past, this has contributed to incremental loss of habitat, productivity and biodiversity. The trend in Europe and the USA now is one of rationalisation of plant and release of land. The pattern in the Far East, and probably elsewhere in the world, is the reverse.

Ways to Reduce or Eliminate the Breach

The rationalisation of plants will potentially reduce the area of land taken per unit of production. Any future expansion of the industry on to new sites would need to include an assessment of this impact, and options of minimisation and mitigation. For example, use of "brownfield" sites for future development will contribute to increased compliance with System Condition 3.

Within large plants, there are often areas of land in which biodiversity can be encouraged. This should be pursued whenever possible not merely as a matter of good practice, but also to go some way towards offsetting the overall habitat take of the industry. (This theme is explored a little further on page 31.)

3.3 Transport

Considerable transport is associated with the delivery of raw materials, manufacture, processing, distribution, utilisation and disposal of PVC products. Transport infrastructure, especially for road, covers large areas of land and destroys natural habitat. The PVC industry contributes, albeit to a limited extent, to this land loss.

Ways to Reduce or Eliminate the Breach

Rationalisation of the use of transport so as to minimise distances would be a significant contribution towards sustainability. So too would optimisation of the transport mode, for example wherever possible switching from road to rail or ship, which have less overall negative impact on the environment.

In practice, this rationalisation has to be balanced with risks to health and the environment from accidental loss. This illustrates the need to address sustainable development with an holistic framework that takes account of human and environmental as well as economic factors.

3.4 Waste Disposal

Much of the waste PVC products in the foreseeable future will be deposited in landfill sites or else incinerated (concerns about this have been raised throughout this report and are also addressed in detail in Appendix 2: Closed Loop Manufacture). Although many landfill sites are already degraded areas such as quarries, this waste nevertheless contributes to the problem of loss of land area and quality arising from waste disposal in the long term. It would appear to be inevitable that a proportion of waste PVC products will continue to go to landfill into the medium term, because there are currently no other sustainable means of disposing of it. This dependence is exacerbated by waste streams containing mixtures of materials from which it is very difficult to separate the PVC.

Landfill sites across the UK are scarce; indeed in London, North Wiltshire and many other areas all available sites have effectively been used. It seems inevitable that the physical availability and the acceptability of landfill, together with increasing costs brought about by the Landfill Tax, will ultimately enforce more sustainable uses for waste PVC and other materials. There is also a proposal from the German government to the European Union (EU) to ban all plastics from landfill by 2005, and ensuing EU legislation to this effect is viewed as inevitable by many. PVC manufacturers and those heavily reliant upon the product in the UK industry are advised to address this sustainability challenge proactively before "hitting the walls of the funnel" (to use the TNS metaphor).

Whether a strictly limited amount of PVC can be permitted to go to landfill and still be considered sustainable is a matter for further analysis. In the absence of consensus on this principle, and the amounts of waste material that might be involved, the target of "zero waste" is the most helpful objective in determining the path of sustainability. (For further details, refer to Appendix 3: PVC in Landfill.)

Ways to Reduce or Eliminate the Breach

Reducing the amount of waste produced by increasing the level of reuse and recycling will be the most effective way of tackling this problem. The wider benefits of full closed-loop re-manufacturing have already been outlined previously in this study, and the PVC industry (with heavy users of PVC products) are strongly recommended to take ownership of the full life cycle.

Question 3(b): Is it possible for the industry to commit itself long-term to a closed-loop system, eliminating waste disposal to land?

3.5 Water Use

Substantial quantities of water are used in the manufacturing and processing of PVC. (The extent to which water use is minimised and recycling already takes place has not been evaluated during this study.)

Ways to Reduce Eliminate the Breach

Systems to reduce and recycle water will contribute to tackling the world-wide and growing problem of water shortage.

*Question 3(c): **Is it possible for the industry to make further specific commitments to reducing its impacts on the water environment?***

3.6 Mining of Stabilisers/Fillers

Mining inevitably destroys habitats, either directly or indirectly, and should therefore be managed at the minimum level consistent with meeting human needs. Although the relative quantities of minerals used by the PVC industry are not large, they nevertheless make a contribution to this habitat loss and therefore breach System Condition 3.

Ways to Reduce or Eliminate the Breach

Reduction of the amount or substitution of stabilisers with less damaging alternatives and greater use of recycling will impact on this problem.

General Notes about Habitat Loss

Even with all the anticipated improvements in efficiency, recycling, changed transport modes, etc, the activities of the industry may cause some loss or damage to habitats in the medium term. The loss of natural productivity is a serious issue world-wide, as nature's life-support services ultimately support all life, provide the primary resource for business and contribute to "quality of life". Since loss of natural habitat, and the biodiversity and productivity that they support, is often a matter of "death by a thousand cuts" – small incremental damage resulting in substantial cumulative loss – there is a need to address habitat in all development decisions across the PVC life cycle. Loss of biodiversity may be the most serious problem facing the world in this millennium. Funding compensatory habitat restoration schemes, either as mitigation or else going further into restoration of habitat previously taken, could eliminate the net impact of the above.

*Question 3(d): **Is it possible for the industry to commit itself long-term to ensuring that any habitat loss or deterioration caused by its activities is compensated for by investment in habitat regeneration schemes?***

III.(4) System Condition 4

System Condition 4

We must be fair and efficient in meeting basic human needs.

This means that, in a sustainable society, social and economic relations would be organised in such a way as to maximise the chances of meeting System Conditions 1 to 3. Basic human needs must be met with the most resource-efficient methods possible, including equitable resource utilisation and distribution. This System Condition differs from the former three in that it relates less to the underlying science and more to the promotion of social justice, and operates at the social and economic level. It does so by addressing four preconditions:

1. All social and economic relations would be based on the indivisibility and total interdependence of all living organisms;

2. People's basic human rights (as laid down in the *United Nations Universal Declaration of Human Rights*) would be secured;

3. Social relations would be organised in such a way to enable all people to meet their basic physical, psychological and spiritual needs; and

4. Economies would be structured in such a way as systematically to reduce exploitative and ultimately unsustainable differentials in both wealth and power.

Business sustainability is about far more than just improving economic and environmental performance, and relationships with shareholders and customers. A genuine commitment to sustainable development also acknowledges responsibilities to employees, as an integral part of the communities in which an enterprise is located, to business partners, suppliers, selected NGOs (non-government organisations) as well as the environment. Corporate reputation and its "license to operate" around the world depend upon meeting these wider responsibilities while competing effectively. Good business is, by its very nature, socially as well as environmentally responsible business. The recently-published *Committee of Inquiry* report (Forum for the Future, 1999 – see References) acknowledges that businesses with this wide "stakeholder" focus can be both competitive in the short term and more sustainable in the long term than those with a simple economic bottom-line focus.

Whilst these social dimensions are also to do with the cultural environment in which enterprises operate, the establishment of a proactive attitude towards them is an indivisible part of a true commitment to sustainable development. The principal ways in which the PVC industry can at present contribute to issues of fairness and efficiency are listed in Table 4, which basically mirror the above four preconditions, together with summaries of the options for dealing with them. A summary is given subsequently of the way System Condition 4 is breached and how these breaches can be reduced or eliminated.

Table 4: Summary of System Condition 4 Analysis

Item	Nature of Breach/Note	Ways to Reduce/Eliminate
4.1 Indivisibility and Interdependence	Poor understanding of the dependency of the industry upon nature and natural resources	Promote learning and change programmes as part of sustainable development strategy
4.2 Basic Human Rights	No known audit of the ethical dimension of the PVC industry	Evaluate the fair treatment of people and nations across the PVC life cycle Ensure internationally-consistent standards for PVC plant, procurement and disposal Develop dialogue with those affected by PVC life cycle
4.3 Meeting Needs	Waste of material by lack of effective recycling	Make progress toward closed-loop re-manufacturing to eliminate waste
4.4 Reducing Differentials	No known audit of use and distribution of investments and revenues	Work to develop stakeholder interests and knowledge of investment decisions

4.1 The Indivisibility and Interdependence of Living Organisms

Sustainable development depends upon an understanding of the mechanics of the natural world, and how the essential life-support systems of this world ultimately make life and business possible. When natural systems are damaged, all of society, including businesses, is harmed and its activities are constrained. This fundamental understanding is not currently evident in the PVC industry nor, it has to be said, in many other places in society. It is therefore essential to address sustainable development not merely as a technical exercise but as a learning exercise in which all participants understand the purpose for this commitment.

Ways to Reduce or Eliminate the Breach

A genuine commitment to sustainable development acknowledges that change is inevitable. Increasing pressures by society on natural and human resources will ultimately exert pressures upon all industries, and addressing these proactively is a matter not of altruism but of business advantage. The raising of awareness of employees across the PVC life cycle would indicate a commitment to addressing sustainable development as a matter of organisational and cultural change and not merely as a threat.

Question 4(a):Could the PVC industry promote awareness-raising about sustainable development internally, across the PVC life cycle, and externally to the public?

4.2 Securing People's Basic Human Rights

Industry ultimately depends upon both natural and human resources. The consequences of exploitation of natural resources have largely been addressed in consideration of System Conditions 1 to 3. The exploitation of people, by denial of basic human rights in the pursuit of profit, is not merely unethical but ultimately unsustainable. Social justice would take account of a wide range of factors across the full PVC life cycle including, for example, the implications of procurement policies, exposure of the poor to smoke, noise and other pollutants.

The implication of this is also that people everywhere should be treated in an even-handed fair manner – in ways that respect their basic rights – across the whole PVC supply chain. This includes an equitable share of risks and benefits, in addition to standards that apply equally across the globe.

Ways to Reduce or Eliminate the Breach

PVC plants are already being constructed in developing countries, and it is noted that the same high standards of performance are required of the operators who are subsidiaries of major European and American companies. The same principle should also apply to other major players in the PVC life cycle.

However, it is pointed out by critics that the industry is increasingly dominated by large multinationals. There is evidence of growing public mistrust of the "global corporation", and this mistrust is sometimes well-founded. Such organisations need to do more to overcome that mistrust, which otherwise has the potential to affect consumer demand. Looking closely at the way in which they do business, effective and inclusive communication with all stakeholders, local decision-making and sourcing, community involvement and education are some of the steps which should be considered as a means for countering the negative effects of globalisation. Each of these measures can be considered essential to the realisation of sustainability.

Ultimately, it will be the consumer who decides on the balance of risk involved in the use of PVC products. A precautionary approach should therefore be taken to all risks posed to people everywhere in the manufacture, use and disposal of PVC.

Question 4(b):It is possible for the industry to develop effective dialogue with those affected by its products to ensure that there is an appropriate balance between risks and benefits?

4.3 Enabling People to Meet Their Needs

Various materials permit human needs to be met with differing degrees of efficiency. The more efficient the material or process, the more effectively can needs be met and the greater the consequent capacity to meet these needs across a growing global population. Wastage is therefore a primary breach of System Condition 4. At the present time the majority of PVC products at the end of their useful life are landfilled and this is a clear breach of System Condition 4 as it is a waste of potentially re-useable resources.

The PVC industry considers its products make a significant net positive contribution against the criteria of System Condition 4. It is claimed that PVC is energy- and resource-efficient in manufacture and use compared with other materials including other plastics. However, this obviously does not make the material inherently sustainable. There are various claims made by the industry for a range of applications:

- The products are relatively cheap, lightweight, strong and adaptable to many applications. Using cars as an example, PVC (along with other plastics) reduces weight and therefore reduces fuel consumption (although it may produce some additional recycling problems at the end of life).

- Over 50% of PVC is used in connection with buildings where its light weight and thermal properties are beneficial.

- The above benefits are also available to users in the developing world. It also has some specific benefits there, for example for water irrigation schemes. Sadly, the use of PVC sheets for shelter in refugee camps is one of its more striking uses in recent times.

- PVC is the best material so far discovered for many medical applications with up to 45 years use and, it is claimed, no known adverse reactions. Replacing it by alternative materials would almost certainly be more expensive in the short term, and the phase-over may also carry risks. However, some medical supply companies are seriously addressing the challenge of finding new materials to replace PVC. This should further deepen commitment by the industry to address sustainable development proactively as a key business opportunity.

- Its use in packaging is strongly questioned. Whilst PVC has unique barrier properties, is non-tainting and may reduce wastage, it is perceived to be used to excess in packaging and to be difficult to recycle. All of these factors have to be weighted together, and fully sustainable solutions sought long-term.

The industry has been accused of generating the production of "frivolous" commodities in the developed world instead of prioritising the meeting of basic needs world-wide, although this is more a question for society than the industry. This is of course as much an issue for the equitable spread of resources world-wide by society as it is a specific point for the PVC industry. It is nevertheless a breach of System Condition 4 if this luxury usage compromises the capacity of others to meet their basic human needs.

Ways to Reduce or Eliminate the Breach

The industry should continue to ensure that it continues more effectively to help people meet their needs in ways that eliminate risks.

Progress towards the closed loop re-manufacturing of PVC would be a major step towards sustainability. It is also important to consider the life-cycle sustainability of PVC on a specific application-by-application basis.

4.4 Economies Structured to Reduce Differentials

The extraction of raw material, the manufacture, supply, use and disposal of PVC products have regional as well as international implications. Multinationals have often been accused, sometime justifiably, with accruing inequitable proportions of profit from regions in which they operate and from the people that their activities affect. The same accusations have also been levelled at procurement strategies that some might view as exploitative.

Ways to Reduce or Eliminate the Breach

The PVC industry should ensure that its procurement, manufacturing and other procedures do not use human resources without appropriate recompense.

Priorities with regard to employment, supply chain management, community welfare and fair trade should be examined.

Question 4(c): ***Is it possible for the industry to commit itself to developing a stakeholder dialogue, inclusive of all sectors of society touched by PVC manufacture, use and disposal, in order to accelerate progress towards sustainability?***

IV. Challenges for the PVC Industry

The analysis above, particularly the questions raised, highlights a number of significant breaches of TNS System Conditions. The PVC life cycle is clearly unsustainable taking into account current methods of manufacture, conversion, use and disposal. Whilst it may also be true that alternative materials may be no more or less sustainable, sustainable development is a substantive challenge and is best addressed proactively.

Addressing the Challenge

Significant eco-efficiency improvements have been made in recent years, under the various *Codes of Practice* such as the recent NCBE *Eco-efficiency Code of Practice for the Manufacture of PVC.* As outlined in the Introduction and elsewhere, further progress is to be anticipated in future. However, current and anticipated changes are not sufficient in themselves for the industry to achieve sustainability (although the *Environmental Charter for UK PVC Manufacturers* developed by NCBE does incorporate sustainability issues).

The challenge of achieving sustainability should not be seen solely as a longer-term issue. Measures being taken by governments world-wide in response to their Kyoto Protocol commitments for reducing greenhouse gas emissions, for example through energy/carbon taxes, will impact on the economics and potential viability of all sectors of the economy. Whilst PVC may be more energy-efficient in manufacture than many alternative materials, this does not in any way exempt it from the challenge. Similarly, legislation on the use of phthalates will force the industry to seek alternatives because of concerns about their possible dangers. The EU Directive on Packaging Waste is also calling for increased recovery rates in the relatively short term, and also places specific responsibilities on producers. All of these factors indicate the accelerating trend of restrictions on PVC, and the way that the metaphorical "funnel" of TNS is constraining industry's room for manoeuvre. This in turn signals the business advantages of addressing sustainable development as a business priority. The only other option is to "hit the walls" of the resource funnel in the form of rising resource and waste costs, adverse public opinion and supply chain pressures, more stringent legislation, health scares, vulnerability to attack from "green" activists and reactive policies. The advantages of being proactive, rather than being bounced reactively into policy changes, should be clear to all readers.

Based on the System Condition analysis, a number of questions are posed which have been summarised into five key challenges. If these challenges are accepted and addressed proactively in the longer term, they would mark a major shift towards sustainability, and should in our view yield clear business benefits.

Timing

The economics, the technical feasibility, the likely trends in innovation and the appropriate phasing of these radical changes are a matter for debate. A key element in this discussion will be timing. Introducing changes risks making PVC less competitive in the short term. Conversely, delaying change perpetuates the risk of having to react to changes in resource costs, more stringent legislation, hardened public opinion, etc. Delaying change too long will also attract accusations of "greenwashing" with no substantive commitment.

For this reason, steps that may be taken today that will lead eventually to further steps towards a fully sustainable life cycle are encouraged. This continued exploration of a vision, and the necessary steps towards it, must be taken openly with no presumption that PVC has or has not a place in a fully sustainable future.

Five Key Challenges

Five key challenges deriving from the analysis using the TNS framework, and the questions raised, are outlined below. Against each, some short-term steps are suggested which would move the industry towards sustainability. However, it is critically important that these should be seen as initial stages in the radical long-term commitments proposed for the industry if it is to meet the challenge of sustainable development. The difficulty in meeting these commitments is appreciated. However, the dangers of unsustainability have also been spelt out in the report.

Challenge No. 1. The Consumption of Hydrocarbons

PVC consumes large quantities of hydrocarbons, which end up essentially as carbon dioxide and water vapour in respect of the energy segment (which contribute to climate change) and in landfill in respect of the inherent hydrocarbon content of the products. A key challenge for the industry therefore is to reduce this carbon burden. Specific targets to progress towards a carbon neutral industry include:

- achieve major improvements in energy efficiency in manufacturing plants.
- improve generation efficiency, for example by increased use of CHP systems.
- develop programmes for a progressive increase in the use of renewable energy sources for generation of electricity.
- set targets for substantial reductions in transport energy use by improved efficiency, backloading (ensuring that transport does not run empty), rationalisation, and selection of optimum mode.
- analyse the feasibility and carry out a Life Cycle Analysis of changing feedstocks from hydrocarbon to biomass or other sources.
- develop co-operative programmes to substantially increase the recycling of waste products including a major effort to work with other agencies and users.
- agree specific targets for adopting carbon sequestration schemes.

In order to achieve sustainability :

CHALLENGE No.1

The industry should commit itself long-term to becoming carbon-neutral.

Challenge No. 2. The Recycling of Waste PVC Products

Currently, up to 90 % of waste PVC is landfilled. This is a clear breach of all System Conditions: It is a waste of resources, it occupies land and may lead to toxicity problems from landfill leachates. Landfill may be an immediate solution, but it does not immobilise waste in perpetuity. It therefore results in the gradual accumulation of chlorinated hydrocarbon products, and the associated heavy metal and other additives, in nature.

As outlined previously, wider concerns and declining acceptability of incineration of PVC should be a cause of concern to the industry as well as a major sustainability challenge.

Increasing the amount of effective, economic and ecologically sound recycling, to a point where a closed-loop system is in force, is a major challenge for PVC (and for the whole of the plastics industry). EU proposals from the German government, outlined previously in this report, reinforce the high probability that this is a short-term rather than a long-term sustainability challenge. To be effective, any recycling programme will have to involve many stakeholders including processors, customers for the product, local and national authorities. However, PVC manufacturers and high-volume users of PVC products have a vested interest in providing the concerted push to accelerate the process, which has so far been unsatisfactory, thereby seeking to ensure its own long-term security.

Many short-life PVC products are currently disposed of rather than re-used; this is most obviously the case with packaging. Packaging has a significant beneficial role in the protection of products and the minimisation of product wastage. However, PVC waste, often soiled, commonly joins mixed waste streams. Joint activities are called for between the PVC industry, the packaging industry and the final users, to increase the amount of multiple-use packaging. Packaging presents a substantial challenge in respect of sustainability.

Even with greatly increased efforts, it has to be accepted that it will not be feasible to recycle/re-use all waste PVC products. Significant quantities will continue to be landfilled in the foreseeable future. The implications of this for the sustainability of the industry will have to be faced, and a proactive strategy put in place to tackle the economic and social acceptability of this, in the light of imminent limits to landfill capacity.

The European Commission is currently engaged on a study of the waste management of PVC across a wide range of applications (the so-called Horizontal Initiative). The outcomes of the study are likely to have a significant impact on the PVC recycling industry.

It is understood that EVCM will be constructing a pilot plant for feedstock recycling. Developing this to full-scale production will be an important step for the industry. The European Directive on Packaging Waste requires a plastic recovery rate of 50 % to be achieved by 2001. The current trends suggest that this target is unlikely to be met without changes in the regulations and/or greater incentives for increased recycling. A collaborative approach across the whole life cycle is essential if this is to be achieved.

Specific targets for action to move to a "closed-loop" system (see Appendix 2: Closed Loop Manufacturing for general principles) therefore include:

- enhance joint efforts with stakeholders to increase the amount of recycling and re- use of PVC products, including investigation of obstacles and infrastructure necessary to overcome them.

- set specific targets for the above increasing progressively over time.

- continue investigations into the potential toxicity problems arising from PVC in landfill and where required ban substances from landfill.

- analyse the sustainability implications of the extent of continued use of landfill and alternative waste disposal routes, including incineration.

- develop the pilot plant for PVC feedstock recycling to full scale production.

In order to achieve sustainability:

CHALLENGE No.2

The industry should commit itself long term to a closed-loop system of PVC waste management.

Challenge No. 3. Emissions of Organochlorines

Organochlorines exist as products or by-products of PVC at all stages of the process. They are possibly the most controversial aspect of the industry. Many of them are toxic and, when released, can cause harm or accumulate in nature under certain conditions where they may have long-term effects. Others break down fairly readily into hydrochloric acid which, whilst not toxic in low concentrations, does contribute to acidification, a major environmental problem in Europe and world-wide.

Major progress has been made within the manufacturing industry to reduce the level of emissions at the manufacturing stage but, even at the very low percentage level of releases currently achieved by best practice, there are significant tonnages of, for example, VCM and EDC released into the atmosphere. Where these releases exceed the capacity of natural systems to break down and reintegrate these substances (and their breakdown products) without toxic effects, this is clearly unsustainable. Furthermore, by-products consisting of "light" and "heavy" fractions of organic chlorine compounds are formed during the manufacturing process. UK manufacturers claim to have removed all organochlorine substances from incinerator ash through various techniques including chlorine recovery, and this must be verified and upheld everywhere as best practice.

Of greater concern is the release of organochlorine substances, including the accumulation of waste PVC itself in landfill, across the whole life cycle through to disposal. In the absence of clear agreement about "threshold" concentrations that can be fully broken down and reintegrated by natural processes, without causing toxic effects, the Precautionary Principle would suggest a commitment to "zero emissions" as a prudent goal.

Areas for action include:

- minimise further all fugitive, accidental and by-product emissions of organochlorines in plants.
- seek alternative processes to diminish emissions to a level that results in no systematic accumulation of organochlorines in nature (applying the Precautionary Principle where appropriate).
- seek the necessary steps to reduce organochlorine emissions to nature across the whole life cycle such that there is no net systematic accumulation.

In order to achieve sustainability:

CHALLENGE No.3

The industry should commit itself long-term to ensuring that releases of persistent organic compounds from the whole life cycle do not result in systematic increases in concentration in nature.

Challenge No. 4. The Use of Plasticisers and Other Additives

A wide range of other substances are added to PVC to imbue it with the diverse properties required by its end users. Many of these additives are added by PVC finishers and the manufacturers of finished goods without the further involvement of the manufacturers of the basic PVC. In many cases, little is known about some of the additives, or their fate post-disposal. (For details of a study of fate in landfill, refer to Appendix 3: PVC in Landfill.) Nevertheless, all such additives contribute to the sustainability implications of the PVC life cycle. The best interests of the industry are served by becoming fully involved in product stewardship across the whole life cycle of the product. Unsustainability of the life cycle will inevitably have adverse implications for all involved in it.

The endocrine effects of plasticisers have been the subject of intense debate in recent years and, although evidence suggests that the main phthalates used in PVC are not harmful to humans, persistence in some parts of the environment, accumulation in invertebrates and the stimulation of cancers in rats are established. On the basis of this concern, some major toy manufacturers and retail chains have ceased to stock certain toys made of PVC containing phthalates. The EU is currently carrying out a comprehensive risk assessment on the environmental fate of four species of phthalates as part of its assessment of plasticised PVC. In the interim, the EU has introduced legislation about its use in certain applications. There also remain doubts about the dangers arising from leached phthalates, particularly in watercourses as they do not readily degrade if they are absorbed in anaerobic silt. All phthalates should be reviewed, and any bioaccumulative and ecotoxic substances eliminated. From the perspective of the principles of The Natural Step, the nub of the argument is not the debate about exact mechanisms and specific trigger concentrations but rather the overall sustainability implications.
There is still no clear consensus about the details of how these chemicals interact with nature and humans and, given this doubt, the System Condition implies management of all releases across the whole product life cycle such that they can be broken down and reintegrated by natural processes without toxic effects. Given that these levels are not yet known, the Precautionary Principle would suggest that incautious use and

emissions are not sustainable. The sustainability implications of alternatives to phthalates should also be investigated more fully, and not assumed to be "better" in the absence of such an analysis despite having received less negative publicity in the media.

Review of the use of all additives, and serious consideration of their implications, would be consistent with attaining the end-goal of full sustainability. The benefits of so doing, and the consequences of not making this commitment, have already been made elsewhere in this report. Areas for action therefore include:

- determine in which applications it would be prudent to review the use of plasticised PVC, and other potentially problematic additives, at the present time in view of the doubts noted above.

- where there is reasonable doubt about the safety of phthalates, research alternative plasticisers and other additives that do not result in systematic accumulation in nature or toxic effects. It is important to note that alternatives should not be assumed to be more sustainable than known problematic substances in the absence of a sustainability analysis.

- contribute fully and openly to the various studies being conducted world-wide on the potential dangers from phthalates, and on other substances perceived to be problematic.

- ensure that reviews of all additives result in steps towards the eventual achievement of sustainability, including facilitation of recycling and closed-loop systems.

In order to achieve sustainability:

CHALLENGE No.4

The industry should review the use of all additives consistent with attaining full sustainability, and especially commit to phasing out long term substances that can accumulate in nature or where there is reasonable doubt regarding toxic effects.

Challenge No. 5. Sustainability Awareness

Despite the constant attacks faced by the industry, there are as yet only the initial signs of a willingness to address sustainable development as a strategic matter. This is unfortunate as the real commitment to change implied by sustainable development relates to addressing future challenges as inevitable market opportunities, to be tackled proactively. A genuine commitment to sustainable development can help overcome expensive and distracting reaction to issue-by-issue attack. It can also be an inspiration to PVC users and other partners who are essential to achieving full sustainability. Real change is an evolutionary process, involving the raising of awareness and the participation of all players in the industry.

It is therefore suggested that the PVC industry should engage in an awareness campaign such that all those directly involved across the PVC life cycle understand what sustainability means in practice, can participate in progress towards it, and can "sign up" to a sustainable development strategy.

In order to achieve sustainability:

CHALLENGE No.5

The industry should commit to the raising of awareness about sustainable development across the industry, and the inclusion of all participants in its achievement.

V. The 2020 Vision Seminar and its Key Outcomes

The debate about PVC, like many other contentious issues, has become polarised and vociferous. This may serve to highlight potential problems, but also inevitably results in the whole issue becoming mired in controversy to the extent of inhibiting positive progress with sustainable development.

2020 Vision, a collaboration between The Natural Step in the UK and the Environment Agency, is a process for sharing information and seeking consensus on contentious issues, moving the debate forwards in the light of a collective enquiry into the place of that issue in a future sustainable world. The 2020 Vision process uses The Natural Step framework – the science-based model of the sustainable cycling of matter and energy on this planet and an associated set of tools – as a systems thinking approach to structure this debate. The process of informed and inclusive dialogue, based on sound scientific principles, is also important to rebuild public confidence in science. The Environment Agency has a key role to play as an arbiter and wise manager on behalf of the environment and wider community, and in informing its own policy decisions.

2020 Vision Seminars involve an invited expert audience to share information and to engage in consensus-based dialogue. **2020 Vision Publications**, covering the outcomes of the first two seminars in the 2020 Vision series – on GMOs and PVC respectively – can be found at the web site of The Natural Step office in the UK (www.naturalstep.org.uk), or obtained by contacting that office directly (details on the back cover of this document).

The 2020 Vision Seminar on PVC

The 2020 Vision Seminar on PVC took place on 20th March 2000, kindly hosted by Tesco Stores Ltd at their Ponsbourne Park training centre, to explore the diverse issues connected with the debate about PVC. The seminar comprised a closed meeting of invited experts, engaging in dialogue leading towards consensus positions about the role of PVC in a sustainable world, and the things that could be done today to work towards realising it. Delegates are listed at the end of this section. It is acknowledged that there was a bias in numbers towards PVC industry representatives, although it is important to acknowledge that Greenpeace elected not to take part in the seminar as their position is that PVC should be banned, not managed. Also, Dr Paul Monaghan of the Co-operative Bank was unable to attend, but had through correspondence expressed the Bank's position on eliminating PVC.

The 2020 Vision seminar was initiated by a series of expert presentations, aimed at information-sharing, and providing a baseline of factual information covering all of the diverse implications of the PVC life cycle. An outline of the TNS framework was provided to enable delegates to engage in structured debate. The most substantive input to this workshop was an earlier draft of this document, augmented by the following presentations:

- The hazardousness debate at international level

  Roy Watkinson, Hazardous Waste Policy Manager, Environment Agency

- The science & implications of phthalates

  David Cadogan, Director, European Council for Plasticisers and Intermediates

- The science & implications of stabilisers

  Peter Donnelly, Vice-president, European Stabiliser Producers' Association

- Management of PVC waste

  Rolf Buehl, Chairman, PVC Waste Management Committee, European Council of Vinyl Manufacturers

- A life cycle of PVC in building applications

  Jane Anderson, Researcher, Centre of Sustainable Construction, Building Research Establishment

- The Co-operative Bank's position on PVC

  Delivered as a set of bullet points in the absence of Dr Paul Monaghan, The Co-operative Bank

The process of the remainder of the day was towards *consensus-building* about the place of PVC in a future sustainable world. The focus on consensus encouraged conflicting views and opinions to be aired, structured by the holistic framework of sustainability of TNS, without encouraging people to establish polarised positions. Through a structured approach, based on the beliefs, concerns, questions and other views of all delegates, the consensus-building process led towards:

- identifying knowledge gaps and questions remaining;
- determining points of agreement; and
- agreeing on ways forward.

Points of Agreement

A major part of the outcome of the seminar was a set of **points of agreement**. These were evolved during the day by inclusive dialogue, and presented and discussed in the concluding plenary session. These points of agreement – which were unusually numerous and diverse when compared to typical debates about PVC – are listed below:

- Sustainable development drives towards a goal of full sustainability, imposing substantial challenges upon the PVC industry. The rest of society also faces substantial challenges.

- The PVC industry acknowledges the need for change, and recognises that it must act. There is evidence of rejection of the material by some major manufacturers and users, as well as a need to satisfy investors in the chemicals industry that this risk is being managed.

- There was broad agreement to address the "five challenges" outlined in the draft report (given here in section IV) that will drive innovation towards sustainability. However, no timetables were established for dealing with the issues raised.

- There is a need for more sustainable technologies for the production of PVC, including its feedstocks and its various additives.

- There are issues relating to the chemical contents of finished PVC products, and their fate if landfilled or incinerated, that raise particular concerns for health and the environment.

- For substances which are not persistent or bioaccumulative, "zero emissions" may be an aspiration but not necessarily a precondition of sustainability. However, where there is reasonable doubt about the level of emission that nature can break down and fully reintegrate without toxic effects, the Precautionary Principle should be invoked.

- If PVC is to become fully sustainable, waste must be eliminated through cyclic use. Reductions, reuse and recovery all form part of this strategy. (Recovery can mean either recycling or energy recovery, although energy recovery is not a cyclic use.) Collection and sorting infrastructure and technology are needed to achieve this.

- Therefore, the PVC industry cannot achieve the end-goal of a sustainable PVC life cycle in isolation. The PVC industry needs to become sustainable within a sustainable society. It needs to engage society, other sectors of industry and Government – in fact all stakeholders – in its achievement.

- The PVC industry needs to demonstrate to investors its management of risk as part of its commitment to sustainable development.

- PVC should be treated in the same way as other materials. Or, to put it constructively, equal scrutiny should be given to all materials if we are truly to be tackling sustainable development. There is a need for a level playing field with other materials used by society, all of which will ultimately need to be evaluated as thoroughly as PVC if we are truly committed to sustainable development. Misapplication of the Precautionary Principle – in the form of "knee-jerk" reactions to PVC (or other materials) in favour of materials that may be no more sustainable – is a particular problem.

- There is a need for external communication by the PVC industry to engage all relevant sectors of society into the solutions to these problems. The PVC industry must be a leading partner in this.

- We need to balance economic sustainability with social and environmental aspects.

Next Steps

During the final plenary session, delegates proposed **next steps** to take the debate forward in the light of the issues raised during this one-day workshop. A number of key points emerged:

- For PVC industry representatives to develop a sustainability proposal for senior managers on issues raised at the "2020 Vision" seminar. This should be based on the "five challenges" outlined previously, as well as the other issues raised in the 2020 Vision Seminar.

- Armed with these new insights and commitments, to re-engage in debate with the NGOs. (Environmental NGOs, and in particular Greenpeace, have withdrawn from direct debate with the industry and instead taken an issue-based approach to banning PVC. Many players in industry want to reopen this debate.)

- For the PVC industry to promote recycling, where it makes sense, by:

    - educating key staff in the retail sector, including how to identify PVC to aid separation;

    - educating the construction sector on reducing volume, what can be recycled, exploring ways to get "off cuts" back for recycling, and how to find other quick "wins"; and

    - learning from examples in other countries.

- For the wider UK PVC industry to read and respond to this report, and also to take the outcomes to the global PVC industry (including suppliers of additives as well as PVC converters) via various trade organisations and conference presentations. Ultimately, CEO approval and positive endorsements from within the industry will be required, together with an agreed timetable for achieving significant steps on the route to sustainability.

- To produce a public statement once the sustainability proposal has been approved.

- To engage the Environment Agency and other relevant regulators in the process of The Natural Step. The role of the Agency in the PVC life cycle was not universally understood, neither was its role in monitoring across international boundaries and in providing guidance to UK companies operating overseas.

- To develop dialogue that reaches out and convinces NGOs.

- For the industry to advertise its commitment to a wide range of stakeholders, so it gets the due benefits of recognition. Engaging stakeholders is a far from trivial step. A good deal of the challenge of sustainable development for PVC, and indeed for society as a whole, rests in overcoming obstacles posed by the "throw-away society", the fashion industry, consumer expectations and habits, etc. Economic barriers, and the inadequacies of education and other societal behaviours, were also raised as reasons why so much end-of-life PVC ends up in landfill or incinerators rather than being re-used.

Ways Forward

This evaluation is part of the continuing consensus-building process; it is recognised that consensus-building is a process and not an end-point. The views and needs of a wider range of stakeholders must be tapped as a basis for assessing and managing the production and use of the material in a wise and sustainable way. Whilst scientists have a key role in predicting the scientific implications of the technologies, they are not always best placed to propose policy and best practice to take account of the wider needs of society and a sustainable future. For this reason, a more inclusive approach to policy-making is required.

The ideas and findings in the report show that there are many reservations about PVC, but also many benefits. In many cases, risks associated with these benefits may not have been determined. However, in order to make progress, further actions are required such as:

- continuing to build consensus and awareness of PVC issues relating to a sustainable future through further work with the participants, who will also be taking these issues forwards themselves;

- widening the process to include others from within the Environment Agency. This could include circulating ideas generated on the day and running further events designed to make progress on the issues raised for the Environment Agency;

- exploring ways of taking forward the ideas and options raised on the day with other decision-makers, researchers and regulators, in conjunction with other key stakeholders representing wider society and ordinary peoples' interests;

- seeking collaborators (e.g. other UK government and European agencies, and non-government agencies) to develop rigorous regulatory guidelines and frameworks, and relevant research, consistent with the objective of sustainable development;

- developing further the "whole systems" view, not just a traditional environmental focus, and also explicitly including consideration of the required changes in the economic environment that would drive forward a more sustainable PVC life cycle;

- developing a stakeholder analysis to elucidate ways for further dialogue and consensus to build around the issue. Ideally this would include bringing together the widest possible cross section to explore the issues in an informed way.

Concluding Notes about Workshop Outcomes

It is important to note that the ideas and findings in the report include substantial reservations about PVC, some submitted by a former customer (The Co-operative Bank). There is also recognition of a wide range of benefits, social and economic, although all associated risks may not yet have been determined.

In conclusion, it is important to recognise that consensus-building takes more than a one-day event. However, there was a general perception amongst delegates that this event had taken the debate forwards.

Who Took Part in the "2020 Vision" Seminar?

From the Natural Step
David Cook, Chief Executive
Dr Mark Everard, Director of Science
Anna Kennedy, TNS Gloucestershire Project
Mike Monaghan, TNS Researcher
Jonathon Porritt, Chairman of TNS in the UK
Diana Ray, TNS Facilitator
Maggie-Jo St John, Development Coordinator

From the Environment Agency
Charlie Corbishley, Policy Advisor
Liz Greenland, Science & Data Exploitation Manager
Ian Taylor, Environmental Protection National Service
Roy Watkinson, Hazardous Waste Policy Manager
Louise Wolfendon, Senior Environmental Scientist

Other Invited Guests
Jane Anderson, Building Research Establishment
Heidi Bager, Norsk Hydro ASA (Norway)
Erik Bichard, Director, National Centre for Business and Sustainability
Duncan Bowdler, Trade Liaison Manager, Co-operative Wholesale Society
Rolf Buehl, Environmental Affairs Manager, EVC International S.A./N.V. (Bruxelles)
Dr David F Cadogan, Director, ECPI (Bruxelles)

Sue Cosgrove, Tesco Stores Ltd
Peter Donnelly, Regulatory Affairs Manager, Akcros Chemicals
Malcolm Gall, Q.A. Manager, Hydro Polymers Ltd
Jan-Chris Hullegie, Material Resource Coordinator, Nike Europe (Holland)
Brian Jones, HR & Systems Manager, Hydro Polymers Ltd
Jason Leadbitter, Environmental & Regulatory Affairs Manager, Hydro Polymers Ltd
Bob Mantle, Process & Materials Manager, Interface Europe
Roger Mottram, UK External Affairs Manager, EVC UK Ltd
Paul Ovstedal, Technical Director, Waitrose
Annie Peirson-Hills, European Environmental Affairs Manager, Nike Europe (Holland)
Paul Riley, Network Team Manager, Carillion plc
Leonie Smith, Trading Law & Technical, Tesco Stores Ltd
John Speirs, Managing Director, Norsk Hydro (UK) Ltd
Ian Stockdale, Corporate UK SHE Manager, EVC UK Ltd
Ian Taylor, Environment Manager, ICI
John Trampleasure, Director of Fundraising & Development, Forum for the Future
Nigel Waghorn, UK Engineering Centre Manager, EVC UK Ltd
Andy Wales, Sustainability Manager Europe/Asia, Interface Europe

Unable to Attend (but wishing to stay in the 2020 Vision process)
Paul Bowtell, Environment Manager, Asda Stores Ltd
Geoff Brighty, Environmental Toxicology Manager, Environment Agency
Cathy Cameron, DETR
Stefan Carlyle, Head of SATIS, Environment Agency
Ceri Davies, Policy Manager, Environment Agency
Suzy Edwards, Building Research Establishment
Jayn Harding, Deputy Environmental Manager, Sainsbury's
Professor John Krebs, Joint Food Safety & Standards Group
John Longworth, Trading Law & Technical Director, Tesco Stores Ltd
Richard Macrory, University College London
Chris March, Dean of the Faculty of the Environment, University of Salford
George Martin, Business Affairs Director, Forum for the Future
Professor Steve Martin, Director of Learning, The Natural Step
Paul Monaghan, Ecology Unit Manager, The Co-operative Bank
Dr Karl-Henrick Robért, Chairman, The Natural Step international office
Nina Smith, Sustainable Development Secretary, Environment Agency
Jane Stratford, DETR
John R Svalander, Consultant Industrial Affairs, ECVM (Bruxelles)
Bernard Walsh, DETR

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Appendix 1: About the Principles of The Natural Step

This appendix is provided to help readers understand the background to the principles of The Natural Step, and how it can be used as an holistic framework of sustainability against which to assess the future place of PVC (and other issues) in a future sustainable world. The article below, written by Dr Mark Everard (Director of Science, TNS UK) titled *"The Longest of Journeys Begins..."*, appeared on pages 14-15 of the November 1998 edition of the journal Industrial Environmental Management. It is reproduced here by kind permission of Matt MacAllan, Assistant Editor.

"The Longest of Journeys Begins..."

Sustainable development is a sound, necessary and widely-supported concept. But how does one move from concept to practice, and begin applying it in the messy world in which we live? Dr Mark Everard, Director of Science, The Natural Step UK strides out.

Let's be clear, sustainable development goes way beyond mere compliance with basic environmental and social obligations, and is substantially different to "greening" (peripheral "end-of-pipe", "end-of-field", process optimisation, mitigation, or reputation-building measures). Although sustainability has been the subject of myriad definitions, and seemingly interminable debate about detail, the concept is really quite simple. A sustainable system is one that can continue indefinitely. A sustainable society is one that does not impair or overload the life-support systems that provide for its needs. A sustainable business or other enterprise is one that respects nature's limits and the rights of those with whom it interacts, however remotely, and that can thereby be sustained indefinitely. It is that basic and, at the same time, that remote from what we do today!

How then can one get to grips with sustainable development in the gritty reality of day-to-day decision-making? The first step is a realisation that a commitment to sustainable development is about far more than altruism. A more sustainable business or activity will be less disrupted by resource scarcities, reduced environmental "headroom", adverse public opinion, more stringent environmental and social regulations, etc, in a future world in which population is set to increase and environmental resources to diminish. In short, a more sustainable enterprise is one that will pre-empt future pressures and future markets, and will thereby be more competitive.

High-level Principles

Networking and shared learning with those upon whom we depend, and who depend upon us, is also essential since sustainable development touches all aspects of human life and is therefore not something we can ever hope to achieve in isolation. And, since the application of sustainable development pervades all sectors of society, a set of high-level principles are therefore required to offer a generic, yet robust and science-based, framework for the development of a shared vision, and for wise decision-making.

The Natural Step (TNS) was developed in Sweden some nine years ago to address this gap between the idea and its widespread practice. It has proved highly successful in influencing decision-making across Swedish society - in business, in local and central government, in education and in the home. And it is now beginning to spread across the world.

TNS addresses the scientific underpinnings of the sustainable cycles of nature, upon which not only our health and survival but also the totality of human interests ultimately depend. Using a systems thinking approach, it addresses the biosphere as a holistic dynamic system, and from the scientific laws that govern this system it derives a set of first-order principles governing how a sustainable society would need to operate. The basic TNS model is illustrated in Figure 1.

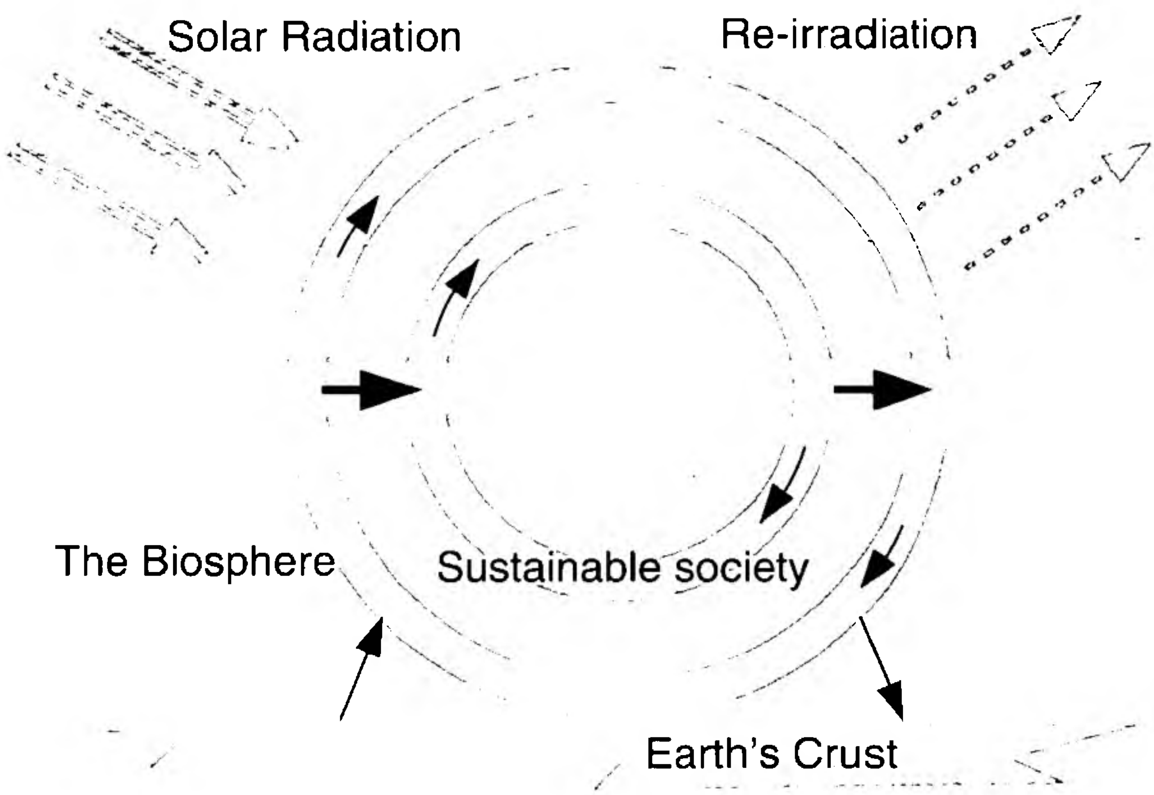

Figure 1: A sustainable society exists within the "rules" of nature's solar-powered cycles. An unsustainable society is one that offends these "rules", and which will inevitably contribute towards the breakdown of the support systems upon which it depends.

Nature's Cyclic Flows

Our present developed society, for example, relies substantially upon linear ("mine-use-dispose") resource flows. Linear resource flows inevitably cause problems since, being alien to nature's cyclic flows of matter, wastes build up in the biosphere in the longer or shorter term, even if we put them "out of sight and out of mind" in the seas, in landfill or into the air. Using the systems-oriented TNS model, it is possible to determine, in simple yet scientifically well-founded terms, the primary ways in which human practices can contribute to an unsustainable world. The four "system conditions" are first-order principles derived from the TNS model, and define the behaviours that a sustainable society would have to observe. These four system conditions are indicated in Figure 2, and then described.

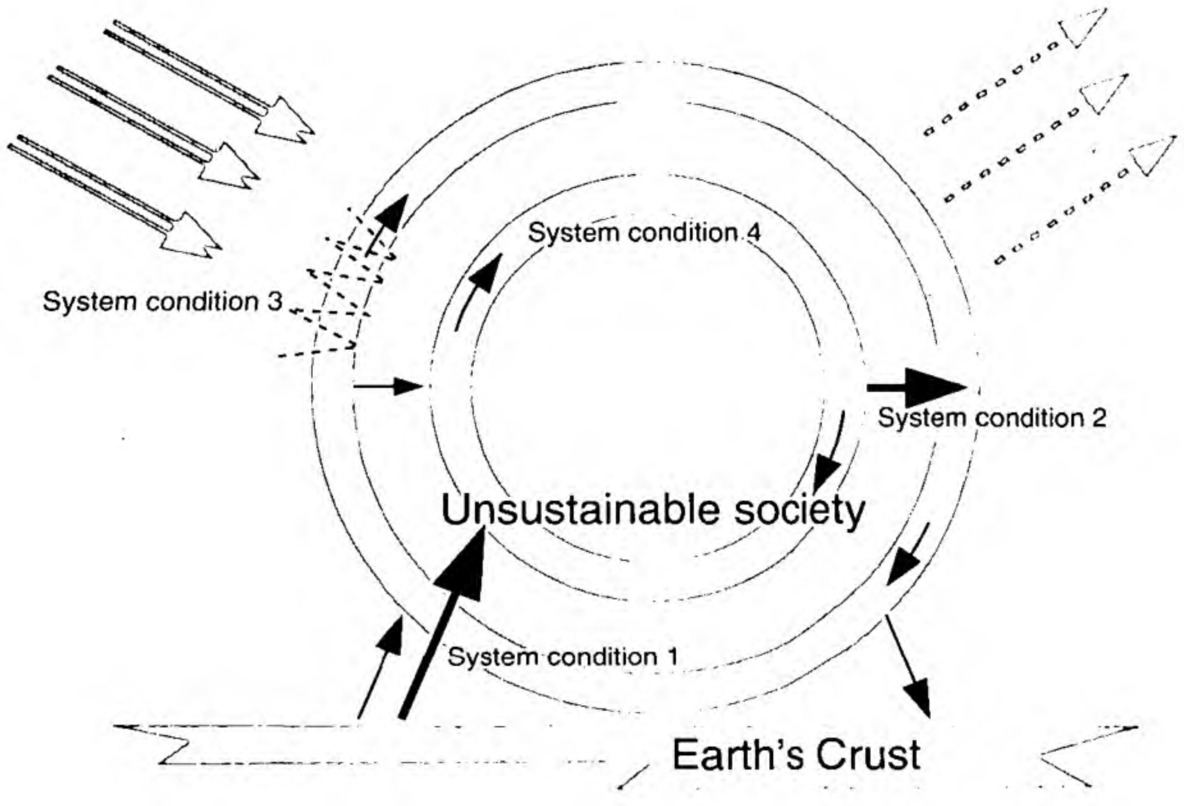

Figure 2: The four system conditions, illustrated by breaches caused by an unsustainable society.

System condition 1 - "Substances from the Earth's crust must not systematically increase in nature" - relates to those substances immobilised in the lithosphere (the "rocky" and largely inert parts of the planet) by billions of years of slow sedimentation and biomineralisation. Clearly, modern developed industrial and agricultural processes breach this system condition extensively, relying on inputs of cheap and abundant energy unlocked from fossil fuels, nutrient substances added to soils, and extraction of metals and radioactive substances. The associated problems of climate change, eutrophication, and increasing soil and water contamination are, however, also well known, resulting from production of wastes at rates exceeding nature's reintegration and deposition processes. As wastes tend systematically to rise in concentration, potentially adverse and unpredictable impacts upon nature and climate also harm the economic and social values deriving from them.

System condition 2 - "Substances produced by society must not systematically increase in nature" - relates to man-made substances. Substances new to nature are processed inefficiently, if at all, by biochemical systems that have evolved over 4.5 billion years in their absence. Breakdown and reintegration of the estimated 100,000 such substances currently in production is therefore slow, leading to systematic accumulations in the biosphere. Predicting tolerable limits, particularly in mixtures and in complex ecosystems, is difficult given our largely incomplete knowledge of their toxicity. We also know that there is a possibility of unforeseen effects revealing themselves in the future - a very recent example is the discovery of endocrine disruption - and it is for this reason that the Swedish Government is considering phasing out persistent bioaccumulative substances, regardless of toxicological data.

System condition 3 - "The physical basis for the productivity and diversity of nature must not be systematically diminished" - addresses the extent and diversity of nature's productive surfaces. The natural processes and productive capacity of nature are the "engines" of biospheric processing, equipped throughout millennia of evolution with diverse ecosystems providing adaptable and efficient pathways. The consequences of over-harvesting natural resources are well-known from the collapse of the world's major marine fisheries, from the scarcity of hardwoods, and from the ever-extending list of extinct and critically endangered species, yet over-harvesting still continues. Equally, we are beginning to become aware of the massive scale of the life support "services" provided collectively by earth's ecosystems, which we diminish or impoverish at our peril.

System condition 4 - "There needs to be fair and efficient use of resources with respect to meeting human needs" - highlights the social considerations permitting compliance with sustainable resource use. Primarily it addresses issues of resource efficiency and equity. Whilst the need for improved resource efficiency is already accepted (Factor 4, Factor 10, etc), we are less responsive to the international dimension of environmental problems, and the contribution of injustices and inequities to social instability.

TNS as a Tool for Sustainability

TNS is a generic, science-based tool to support more sustainable decision-making on a society-wide basis, and as such is applicable across a range of scales. The TNS model is based on nature's sustainable cycle, and the four System Conditions define how a sustainable society must act "ecocyclically". As such, it provides a readily-understandable framework to get to grips with the practicalities of sustainable development, to predict future pressures, to communicate complex ideas within a business environment, to share these concepts with partners and across social sectors, and to make strategic judgements about the steps we need to take now towards a more sustainable future. It helps us address the fact that we cannot realistically hope to achieve sustainability immediately in a world that is far from sustainable, but enables us to "navigate" increasingly towards sustainability through incremental decisions.

The Natural Step is now operating in the UK as a part of Forum for the Future, the charity established by Jonathon Porritt to promote practical commitment to sustainable development across UK society, and the scientific work of TNS UK is kindly supported by the Environment Agency. There is clearly a great deal more to The Natural Step than it is possible to convey in this brief article. We believe that TNS offers a unique tool for getting to grips with sustainable development, for putting it into practice within enterprises, and for doing so as a matter of "enlightened self-interest".

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End of Appendix 1

Appendix 2: Closed Loop Manufacturing

Nature's and Society's Resource Flows

The sustainable cycles of nature on this planet result in no net generation of waste. Throughout the 4.5 billion years that life has been on this planet, efficient and adaptive ecosystems have evolved that process matter in closed cycles. There are some extremely slow sedimentation and precipitation processes which, over geological time scales, lock some substances away from the biosphere (living part of the planet) into the lithosphere (rocks). However, apart from these slow processes, nature fully processes and re-circulates every substance through complex food webs that are ultimately powered by sunlight. Cyclic resource flows are a feature of nature's sustainable system. "Waste" does not occur.

By contrast, modern human society has chosen to operate many linear processes, and particularly since the commencement of the Industrial Revolution (about 220 years ago). The mine-use-dispose ethos that pervades so much of modern lifestyles and commercial activities in the developed world runs counter to nature's cyclic processes, and the accumulation of wastes in the biosphere has diverse and often unpredictable consequences. This linear resource use is unsustainable where nature's capacity to break down and reintegrate or to immobilise pollutants is overwhelmed. The situation is compounded where society has degraded the capacity or extent of ecosystems to process substances, and where harm to humans results from resource extraction, usage or disposal.

Where society infringes the "ecocyclic" principles of nature, which underpin the TNS science-based model of sustainability (see Appendix 1: About the Principles of The Natural Step), unsustainability ensues with all of the adverse consequences noted elsewhere in this report.

PVC and Linear Resource Usage

As we know from the first law of thermodynamics, the dispersion of greenhouse gases into the atmosphere from the stacks of oil-, peat- or coal-powered generation stations does not mean that they "disappear". Their accumulation in the biosphere is a classic example of the consequences of linear resource flows from mined fossil fuels overwhelming nature's reintegration and assimilation capacities (and breaching System Condition 1). Equally, it would be naïve in the extreme to think that the "dilute and disperse" paradigm for waste disposal to water resulted in simple disappearance of problematic substances (i.e. breaches to System Conditions 1 and 2). And so too landfill. Landfill waste is not immobilised in perpetuity, but rather locked up, potentially for decades, in discrete pockets in the biosphere. The second law of thermodynamics should, however, inform us that everything eventually degrades and spreads. What is out of sight and out of mind in landfills will return to the biosphere eventually. Linear flows of resources such as hydrocarbons, chlorine, stabilisers, plasticisers, etc do not therefore stop at disposal. They are merely detained. Add to this the massive wastage of resources – up to 90% of PVC may end up in landfill at end-of-life in the UK – and the lack of available landfill sites across the UK and Europe, and the case for the unsustainability of landfilling PVC products is made.

The same considerations apply equally to incineration which, aside from the benefits of energy generation, have all of the same disbenefits augmented by concerns about exotic substances produced by the combustion process and subsequently released to the atmosphere.

Closing the Loop

System Conditions 1 and 2 relate to the accumulation of substances in nature. There is no problem with using any material that does not affect the life-support processes that provide us with clean air and water, food, economic goods and "quality of life". It is only when we release substances into nature, and thereby ultimately poison or alter it, that sustainability problems arise. One of the fundamental ways that society can seek to prevent substances "leaking out" into natural systems to is to minimise them, and certainly to eliminate them from trivial applications. Another way, and one that often makes good economic sense, is to use the remaining substances in cyclic ways.

If we use the materials that we manufacture again and again, we place lower demands upon primary resources and transportation from their point of origin, and we ensure that end-of-life waste does not occur. That way, plasticisers, stabilisers, hydrocarbons and other constituents cannot accumulate in nature. Closed loop manufacture is an ideal – remote for PVC and many synthetic materials – but is also ultimately a potentially sustainable option.

It goes without saying that recycling should always be to the highest quality possible.

The Feasibility of Closing the Loop on PVC

PVC has a number of qualities that may aid recyclability:

- recycling is theoretically feasible through physical, chemical (re-melting), and feedstock recovery loops. Indeed many such recycling loops are in operation in Germany (the windows industry), in the UK (bottle remanufacture), in Denmark (cable recycling) within manufacturing plants, and on pilot scales for other applications.

- the UK PVC industry claims to be able to reformulate PVC to suit many uses, including the facilitation of recyclability. It claims that it is technically possible to recycle PVC many times without any significant deterioration in quality as, unlike some other thermoplastics, the polymer chains of PVC do not degrade with re-melting and reuse.

- it is possible in theory to recycle PVC into products of not significantly lesser quality. In Germany, for example, PVC windows are collected and remanufactured into new windows of similar quality, and this is enabled not merely by legal requirements but because it is economically advantageous.

- the chlorine atoms that comprise 50% of the weight of PVC can be detected by X-ray fluorescence, and sorting of PVC from waste streams can therefore be automated. (The sorting system of the Reprise PVC bottle recycling plant in St Helens already operates on this principle.)

- one in three local authorities in the UK have schemes to collect plastics for reuse, so elements of the infrastructure are already in place.

- it is possible to use short-life products such as packaging as a raw material for long-life products such as building materials.

However, in practice, the gap between theory and practice is huge. Only a tiny proportion – perhaps 3% – of PVC is currently recycled in the UK. There are various reasons for this:

- The low level of actual recycling in the UK will remain so without further local, national and international incentives and also without greater pressure from the industry itself. The industry is actively exploring additional voluntary mechanisms to develop significantly more recycling. It is in the long-term interests of the PVC industry to take ownership of these problems and to bring on board partners such as the major users in the construction and packaging industries, the major retailers, etc., who can contribute to a more sustainable future PVC life cycle.

- In order to deliver the necessary infrastructure – structural, social, behavioural, economic, etc – to deliver a closed loop manufacturing system across the whole PVC life cycle, it is necessary for all partners to share both the "pain" and the benefits of its development. The alternative is for all to share the implications of longer-term economic unsustainability of the material.

- The economics currently do not favour recycling in the UK. The Reprise plant in St Helens can recycle PVC bottles at a cost (related to washing, sorting, separating, etc) but the economic feasibility of the process fluctuates with market fluctuations in PVC price (which varies between £350-750 per tonne). Globalisation may also make production overseas from virgin PVC cheaper than domestic recycling, as has occurred with at least one major computer manufacturer. The Polluter Pays Principle may not be well observed by the economic system, which may need to be redressed.

- There is a public expectation, engendered by the history of linear resource use, that products made from recycled materials should be cheaper. This must be challenged, and the perception changed, for PVC as indeed many other materials.

- Collection remains the key issue. All sectors of society, as well as the behaviour of individuals, are crucial to this.

- Although the UK PVC industry does not believe that present formulations impose a barrier to efficient recycling, it is theoretically possible that some additives in finished products could compromise the possibility of recycling, or the quality and acceptability of recycled products, decreasing substantially the overall sustainability of the material. This has to be managed as both a risk and an opportunity as part of an overall sustainable development strategy.

- Greenpeace express reservations about recycling of PVC, not merely because they campaign against chlorine itself, but also because they believe recycling merely creates new markets and accelerates demand for PVC.

- Realising the cyclic ideal must embrace wider sectors of society – supply chain management, development of a robust system for when PVC prices are low, collection, sorting, etc.

The question has to be posed as to whether it is feasible to develop a closed system for PVC, and further exploration and implementation are a priority for all.

Other End-of-life Uses of PVC

The closed loop manufacturing proposal is suggested as a helpful way of moving towards full sustainability (system condition compliance). However, there may be other ways of using PVC waste constructively that help with improving the efficacy and/or sustainability of other processes.

As an example, PVC wastes may be burned with galvanised steel resulting in the stripping off of zinc as chloride. Full zinc and chlorine recovery from the process is reported to result in aiding the recycling of steel, without the production of dioxins, and overcoming the substantial problem of recycling raw galvanised steel (particularly resulting from the automotive industry where PVC may be bound to galvanised metal parts). This same process, devised by a Professor Fray and published in a scientific journal (Tailoka and Fray, 1997 – see References) is also reported to aid the recycling of Ni-Cd batteries. No sustainability analysis has been conducted on this claim nor any judgement made about the sustainability of galvanised steel itself, nor about this process. However, this example is included to illustrate the point that some non-cyclic usage of PVC that might not otherwise be suitable for recycling may possibly contribute to increasing the sustainability of other industrial processes.

Debate About Efficient Rates of Recycling

There are some doubts within the PVC industry about whether higher levels of recycling (approaching 100%) are better from a sustainability point of view than the optimum levels indicated by several eco-efficiency evaluations. These doubts arise from:

- higher economic costs in the light of the cheapness of virgin PVC resin (i.e. economic sustainability); and
- significant increases in waste transportation. (Margot Wallström, Commissioner of EU Environment [see References] noted substantial increases in waste transportation in Europe, with waste transport now apparently accounting for up to 15% of all transport in Europe).

There are indeed arguments from the eco-efficiency perspective that efficient rates of recycling can be identified as the balance point between the costs of recycling and the energy efficiency gains of heat recovery from incinerated wastes. This approach tackles the problems from the perspective of today's economic environment and today's acceptability of certain processes.

From the sustainability perspective, the cyclic use of materials (instead of essentially linear material use at present) is ultimately a requirement both to prevent the accumulation of wastes, that will eventually break down and be released into nature, as well as to improve efficiency. Backcasting from this target of full sustainability, one can therefore note that:

- the current economics that support low prices for fossil hydrocarbon and plastic production, and the cheapness of PVC production and disposal, are a result of environmental-and-social-costs that are currently externalised. These will be internalised in a sustainable future, and behaviours and processes that breach the system conditions will also be penalised by regulatory and other means;

- sustainable transport systems will also need to be developed both for this purpose and more widely as part of a more sustainable social infrastructure. A part of the solution may also include developing sustainable transport systems for the waste, ensuring used materials are reprocessed local to the source, and utilising renewable energy for the cleaning, separation and recycling processes.

Sustainable transport and recycling infrastructures need to be developed in parallel with increases in recycling levels for all materials, and ideally with parallel economic changes. The absence of such infrastructures should not constrain the PVC industry and heavy users of the plastic from taking a proactive stance, and bringing their collective influence to bear upon decision-makers across relevant sectors of society.

It is above all important that the challenges of sustainable development for PVC, as indeed for other materials, are tackled by backcasting – as strategic issues with sustainability as a clear end-point – rather than as eco-efficiency challenges to optimise economic sustainability within today's transient limits of acceptability.

Realising the Opportunity

As speakers from the UK PVC industry are quick to point out, PVC has many long-life applications (including pipes, cables, window frames and other building applications). The net result is that a great deal of the PVC manufactured in recent years is still "out there" in long-use products, with lives of anything up to 40 years. Therefore, the amount of used PVC in the coming years that may potentially be returned for recycling will be far greater than today. This surely represents a substantial business opportunity to drive forward the efficient and effective recycling of PVC, with all of the collection and sorting infrastructure that this would entail.

End of Appendix 2

Appendix 3: PVC in Landfill

Much of the waste PVC product is currently disposed of in landfill and there is concern about the environmental impacts this might have. The basic principles governing why landfill of PVC is not ultimately sustainable are already outlined in Appendix 2: Closed Loop Manufacturing. Other specific main causes of concern are:

- does PVC polymer degrade and produce damaging breakdown products such as, for example, vinyl chloride monomer (VCM)?

- is there leaching of additives from PVC, and if so is this a hazard to the environment? The additives in question include particularly phthalates, lead and organo-tin compounds but as we have seen in the system condition analysis, a wide range of other components of PVC has the capacity to accumulate in nature.

- the progressive build up of this non-biodegradable waste.

- the waste of potentially valuable resources.

A major three-year research project, funded by a PVC industry consortium, was conducted jointly by the Technical University of Hamburg and the Universities of Gothenberg and Linkoping. This study paid particular attention to the potential long-term effects of landfill. The preliminary results were reported in June 1999 (see References section).

The main conclusions of the study are summarised here:

- degradation of the PVC polymer was not observed.

- some of the plasticised PVC products showed a partial loss of phthalates.

- the preliminary assessment is that PVC products do not significantly contribute to the concentration of heavy metals in landfill sites.

- the concentration of phthalates and organo-tin compounds in the leachate were not assessed to constitute a risk to the environment.

- heavy metals which do occur in landfill leachates originate from a wide range of sources other than PVC.

The overall conclusion of the report was that landfill was an appropriate disposal option for PVC. The report indicated that further studies would be required to indicate whether recycling as feedstock, energy recovery with incineration or land filling is the optimum solution for PVC disposal.

The study did not employ The Natural Step framework in its analysis.

Several of the findings are open to question in the longer term, for example:

- how available will land sites be long-term?
- can we keep adding to waste sites for ever?
- will waste of a potential feedstock be acceptable?
- substances in nature tend to disperse over longer time scales, therefore can landfill be considered a truly permanent option of disposal?
- will heavy metal/phthalate leaching becoming more significant in future?

This report is currently under review as part of the EU *Horizontal Study*.

End of Appendix 3

Appendix 4: The PROGNOS Report

A major study of the sustainability of the PVC industry was carried out by the Prognos-Group, and presented in a 275-page report in March 1999. The full title of this study is *PROGNOS Report: PVC in Selected Product Systems – A contribution to the Sustainability Discussion.* This independent study involved a wide spectrum of interests including environmental lobbyists, scientists, politicians, representatives of industry and the media.

The study focused on four product areas

- windows
- pipes
- cables
- packaging film

Sustainability indices were defined covering social and economic as well as ecological areas. The study looked at the short-, medium- and long-term impacts of PVC products and compared them to alternatives. The potential for development and innovation of PVC and the alternative products was taken into account in making the medium and long-term comparisons.

The study noted that

> *"The sustainability of products (or materials) can... ...not be seen as an absolute; it is always a 'relative contribution to the sustainability of the entire system' in comparison to other, alternative products. There is therefore no such thing as 'sustainable products'. When the 'sustainability of products' is being assessed the object is rather to assess whether the product has better or worse 'system qualities' than other alternatives in contributing to the sustainability of the entire system or a partial system."*

In general terms PVC was considered on the basis of LCAs to be ***more sustainable*** than alternative products for most applications in the ***short to medium term.*** In the medium to long term it was considered less sustainable, principally because of its requirement for hydrocarbon raw materials.

The PROGNOS report did not appear to place the same weight on the danger of toxic emissions of organochlorines and phthalates as other studies. The reasons for this are that judgement was being reserved pending the outcome of ongoing research into risk assessment.

The report proposed actions to improve the sustainability of PVC in each of the four product categories. It was noted in particular that the medium- and long-term prospects of PVC products are highly dependent on the feasibility of recycling, taking into account the costs and ecological issues.

The report suggests that it has developed a new perspective for viewing the sustainability of PVC. In particular that when assessing sustainability, the economy, society and the environment must be seen as part of an overall system that closely interact with each other. For example, the long-term risks from the use of a potentially scarce resource are seen initially from consideration of exceeding the limit of the environmental system but they will manifest themselves principally as economic and societal (i.e. increase in the cost of raw materials, external impact on society etc). This is of course not a new perspective on the facets of sustainable development.

It further notes that, although a product's contribution to sustainability results from a comparison with competitive products, its ultimate path towards to sustainability is concerned with improvement of the overall system incorporating all alternatives over time.

This in-depth report merits further careful study and, although the approach differs from that of the TNS framework in terminology and approach, some of its findings are complementary to the present study, especially in respect of the longer-term issues.

End of Appendix 4

the NATURAL STEP

A Framework for Sustainability

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