Chapter 1

Capacity-building for sustainable technology development and innovation

This book presents a review and evaluation of the Dutch National Inter-Ministerial Programme for Sustainable Technology Development (STD), which has recently completed its five-year term and is now part-way through a follow-up dissemination phase. The programme missions are to demonstrate that sustainable technologies and the conditions needed for their implementation are attainable in principle in the long term—over a time-horizon of 30–50 years—and to design, test and disseminate innovation-enhancing methods and tools that should be used now to facilitate their timely development. The programme also seeks to foster the co-evolution of technology and the structural and cultural conditions needed for successful technology diffusion, especially by stimulating stakeholder participation in the technology development process. The programme is unusual in that it represents a systematic attempt to influence long-term innovation contexts in favour of achieving a specific societal goal—sustainability—rather than to advance or influence the management of a specific technology. The programme has operationalised a method, which integrates and applies a set of tools, including 'backcasting', the 'factor' concept, life-cycle assessment, Constructive Technology Assessment and 'social niche management'. Most of these tools were available before, but they have not previously been integrated and used systematically in the innovation context. Five years on, the programme can claim to have improved innovation contexts, processes and prospects, directly and indirectly, in relation to several key areas of anticipated future need. It has also contributed, more generally, to building a learning society and learning enterprises. Efforts will continue within the Netherlands to embed these programme successes and to monitor the longer-term effectiveness of the programme beyond its existing term. Meanwhile, other countries and regional blocs are showing interest in developing comparable programmes. In this context, important transferable lessons can be drawn from the STD programme and its experiences.

INNOVATION PRACTICES AND SUSTAINABLE TECHNOLOGY

The STD programme was established with the ambition of bringing about fundamental changes in innovation practices. It arose from an inquiry by the Dutch Commission for Long-Term Environmental Policy (CLTM) into the role of technology in achieving sustainability, whose main conclusion—that usual innovation practices offer no prospect of technology playing anything other than a peripheral role in achieving sustainable development—was one of enormous significance. It even cast doubt over the feasibility of ever achieving sustainability. Central to the conclusion was the scale of the mismatch—at that time still not quantified, but believed to be large—between the societal and technological challenge represented by sustainability and the magnitude of the expected contribution to attaining sustainability that present-day innovation practices could bring. In effect, usual innovation practice was declared incapable of delivering technologies and business plans compatible with sustainability (CLTM 1990).

The limitations of usual innovation practices are due mostly to a preoccupation with existing technologies and with making incremental improvements to these. Incrementalism is deep-rooted in usual innovation processes, especially in defining aspects such as the specification of technological problems and challenges, the specification of search domains and the specification of the relevant actors to be included in the social networks searching for solutions. Generally, specifications surrounding the innovation process are too restrictive and compartmentalised to enable path-breaking solutions to be identified, explored and implemented. Search tends to be confined to existing definitions of both problems and solutions and is carried out by members of existing networks of actors whose foundations are generally rooted in established technologies and whose interests are vested in them. In turn, this characteristic narrowing of definitions and domains owes partly to inertia and partly to the nature of the external and internal incentives that innovators face. Financial criteria and short-termism dominate usual innovation practice[1] and are institutionalised within enterprises, which are the chief custodians of R&D resources and play the leading role in technological innovation (see Chapter 3 for a fuller review).

1 Short-termism is related to a number of factors. One is the required payback period, which is usually short. Another is related to risk reduction. Known technologies are intrinsically less risky than unknown technologies.

However, this diagnosis of why usual innovation practices are generally incapable of delivering sustainable technologies also provides opportunity. The conclusion of the CLTM inquiry was not that technology *per se* would be incapable of playing a major role in the achievement of sustainability or that technologies capable of delivering substantial resource productivity improvements are not, in principle, feasible. On the contrary, members of the inquiry panel were convinced about the possibilities of developing and implementing sustainable technologies. Their concern—reflected in their conclusion—was that usual innovation processes and practices would not lead automatically to technologies compatible with sustainable development. To change the situation, a substantial effort would be needed to try to influence long-term research, technology development and innovation practices in the direction of sustainability. This would depend on developing, testing and diffusing a guiding methodology for 'sustainable technology development'.

THE NATURE AND SCALE OF THE CHALLENGE

Following the CLTM report, a feasibility study was commissioned to define more precisely the nature of the challenge to technology and innovation posed by sustainability and how to tackle it. The feasibility study was set up on the joint initiative of five Dutch ministries: Housing, Physical Planning and the Environment; Agriculture, Nature Protection and Fisheries; Transport, Public Works and Water Management; Economic Affairs; and Education and Science. One part of the study, undertaken by the Advisory Council for Research on Nature and the Environment (RMNO), used an approach based on translating the principles of sustainability outlined in the Brundtland Report (WCED 1987)[2] into quantitative estimates of average per capita annual entitlements to resources and waste emission. The time-horizon for the estimates was 50 years. Two different methods were used for making the translation, but both led to a similar result. Per capita emissions of pollution and consumption of resources need to be reduced, generally to less than 5%–10% of the levels experienced in industrialised societies today. The needed reductions for countries such as the Netherlands typically range from a factor of 10 to a factor of 50 (Weterings and Opschoor 1992). The estimate of the scale of the implied challenge coincides with estimates made around the same time by other groups, such as the Factor 10 Club (see Chapter 2).

The feasibility study clarified three points. First, it quantified the extent of the challenge implied by sustainability—the need for factor-10 to factor-50 improve-

2 The key principles are those of equitable access to global resources among the world's people and of the need for humanity to remain within environmentally determined pollution limits so not to reduce opportunities for future generations to meet their needs.

ments in eco-efficiency. Second, it showed this challenge to be far beyond the range of improvement possible through end-of-pipe technologies and even most 'environmental' technologies, which represent process-integrated improvements to the eco-efficiency of current processes and products. The study reported that, typically, these changes to established technologies could be expected to deliver improvements in eco-efficiency of no more than a factor of 2–3. Third, and most importantly, the corollary drawn was that, to have any chance of meeting the technological challenge of sustainability, it may be inadvisable to follow the traditional route of studying present products and processes as a way of identifying areas for improvement. Rather, it may be better to begin by accepting that sustainable technologies will most often consist of path-breaking approaches to meeting needs that are radically different from the solutions we have in place today.

The feasibility study thus introduced a number of programme-defining concepts. For the first time, it defined 'sustainable technologies' and differentiated these from 'end-of-pipe' approaches and 'environmental technologies'. Sustainable technologies would be ones capable of meeting 'needs' using only a fraction—less than a tenth and maybe only a fiftieth—of the 'eco-capacity' used by today's technologies. Eco-capacity was, itself, introduced as a concept to describe the constraints on the permissible level of resource consumption, ecosystem disruption and pollutant emission that would be consistent with maintaining a stock of environmental capital and a stream of environmental benefits for the use of future generations. The concept of 'need' was adopted from the Brundtland Commission's definition of sustainability (WCED 1987) and its status in innovation practice elevated so that it would be the starting point for innovation processes. This was seen necessary as a means of focusing long-term innovation on strategic issues and of combating the tendency for incrementalism. The factor concept was introduced as a means of operationalising a quantitative goal for reduction in resource use and improvement in eco-efficiency—with progress judged against the benchmark of the demand on eco-capacity made by today's solutions to meeting needs. The factor approach and benchmarking also make it possible to specify a time-path for eco-efficiency improvement, which can be translated into rates of change and used to monitor progress.

Above all, in order to facilitate a process in which the present situation plays little or no role in long-term innovation, a 'backcasting' approach—first introduced into the sustainability arena for end-use-oriented energy systems planning (Goldemberg *et al.* 1985)—was introduced. Backcasting begins with an attempt to envision an acceptable future system state, which takes into account the status of as many important defining constraints and criteria as possible, including the requirement to meet 'needs'. This system state is then used as a reference: for tracing pathways back to the present, for placing milestones along those pathways and for identifying short-term challenges and obstacles that will have to be overcome en route. Progress will depend not only on meeting the technological challenges, but also on co-evolutionary developments in policies, markets, attitudes and behaviours. R&D and innovation efforts have to be directed to all of these challenges. Backcasting thus provides a way of connecting the future and the present. It provides a means of translating a long-term vision of a sustainable future into near-term actions consistent both with achieving that future and dealing with the realities of the present situation. It also provides a basis for a co-evolutionary approach to innovation in which the various elements of the developmental system are viewed holistically and dynamically in terms of interrelationships and feedbacks.

ECO-RESTRUCTURING ANDD TECHNOLOGICAL INNOVATION

Other considerations also contributed to the decision to try to influence innovation practices. Long-term sustainability depends on eco-restructuring to bring the so-called 'metabolism' of our societies and economies—the amount and structure of resource use and waste production—within the boundary conditions described by critical eco-capacities and by human capacities to cope with environmental change or to accept it.[3] As a process, eco-restructuring implies achieving wide-ranging changes in our societies and economies including, especially, a restructuring of production and consumption patterns both in amount and type. This is an inevitable corollary of the important Ehrlich Identity (Ehrlich and Holdren 1971; Holdren and Ehrlich 1974; Ehrlich *et al.* 1977; Ehrlich and Ehrlich 1990).[4] Eco-restructuring also implies cultural and social restructuring, especially of values, motivations and institutions that underlie the criteria used when making produc-

3 It is therefore directly relevant to two of the three central sustainability concerns (for securing a continuing stream of environmental benefits and a continuing stream of economic benefits) and indirectly relevant to the third (for securing a more equitable distribution of entitlement to these benefits across and within generations).

4 Ehrlich's first expression for the important relationship between environmental impact and human activity was I = P.F where I is environmental impact, P is population and F is impact per capita (Ehrlich and Holdren 1971). This equation was later expanded to I = P.C.T where C is consumption per capita and T is the impact per unit of consumption, referred to elsewhere as the environmental impact coefficient (Holdren and Ehrlich 1974). The equation has been explored in works by its author, such as *Ecoscience* (Ehrlich *et al.* 1977) and *The Population Explosion*(Ehrlich and Ehrlich 1990), and has been widely used since to gain insight into the scale of the technological challenge posed by sustainability under different assumptions about eco-capacity, GNP growth/distribution and population growth/distribution (e.g. Goodland and Daly 1992; Weterings and Opschoor 1992). Estimates based on a scenario of halving environmental impacts while achieving equity of access to resources indicated the need for a ten-fold increase in resource productivity by the middle of the 21st century, a conclusion that led to the foundation of the International Factor 10 Club in 1993 (Factor 10 Club 1994). Others have since elaborated on this theme (e.g. Ekins and Jacobs 1994).

tion and consumption choices and the importance ascribed to them, and a restructuring of the incentives that people face when evaluating such choices. This has implications also for decisions on how technologies might be designed and how they might be used.

Shifting toward sustainability thus depends on achieving a set of interrelated changes to the economic structure, profiles of production and consumption, technologies, institutions and organisational arrangements. Eco-restructuring outcomes—evidenced, for example, in changing demands for labour and capital, changing geographies of production, consumption and environmental stress, and shifting distributions of economic and political power—will be similarly pervasive and wide-ranging (Simonis 1994). Eco-restructuring processes and outcomes can be conceived in systems terms as representing a paradigmatic shift from a pre-existing developmental model and trajectory in which low importance has been ascribed to environmental capital and benefits to ones in which the preservation of these becomes a fundamental design criterion for economic, social and environmental development. The shift can be envisaged as equivalent to another industrial or information revolution in which the long-standing *leitmotif* of past innovation processes—of seeking to increase returns to labour—is overridden by that of seeking returns to natural resources, and where the economy is reoriented from a preoccupation with maximising the values of the flows of goods produced to maintaining the values of all capital stocks (including produced goods and infrastructures) and the value of the useful services emanating from these (Weaver 1995).

Against this backdrop, what is the role of technology in eco-restructuring? Although only one element of this set of interdependent elements, it plays a pivotal role. This is because technology is the critical facilitating element, the enabling element that will make eco-restructuring technically feasible and politically viable. Unless technologies are available that, in principle, enable needs to be met without exceeding critical eco-capacities, societies, and more especially political representatives of societies, are unlikely to take measures to penalise use of unsustainable technologies. It is both sensible and politically necessary to ensure that replacement technologies are available, or could be made so in relatively short order, before established technologies and the benefits they bring are moved beyond the reach of their accustomed beneficiaries. These benefits and beneficiaries are likely to extend beyond consumption and consumers to include also the interests of investors, employees and those whose livelihood or influence is vested in established technologies. Candidate new technologies are also needed to help move the debate about the potential costs, benefits and distributional consequences of restructuring and the acceptability of these from the realm of abstract discussion and into the realm of more concrete and tangible analysis.[5]

5 Appropriate technology is a precondition for sustainable prosperity, but it is not all that is needed. Cultural and structural changes must be implemented as well as technolog-

However, this presents a 'Catch 22' to those concerned to shift development trajectories toward sustainability. On the one hand, unless incentives and framework conditions are in place that would make sustainable technologies viable—including the social, cultural and economic conditions that are needed to make a technology acceptable and profitable as well as technically feasible—there is no obvious business imperative for developing such technologies. Since the market will not reward, and may even penalise, sustainable technology innovation, sustainable technologies will not be developed. On the other hand, not having sustainable technologies 'on the shelf' is a barrier to the general restructuring of incentives,[6] which is needed if research, development and innovation are to be focused on the societal goal of sustainability. Except, perhaps, in response to an emergency, a general restructuring of incentives will be politically viable only if this has wide support in society. Before incentives can be restructured, it is necessary to be sure that an evolutionary transition to sustainability is possible that is perceived capable of delivering net benefits and is relatively painless. For this, society needs assurance that science and technology are capable of providing sustainable technologies that will meet needs in acceptable ways. To provide this assurance as well as to provide the basis for transition, some sustainable technologies need to be available 'on the shelf' ready for evaluation and implementation.

A Catch-22 phenomenon in respect to technology development is not new. To some extent, the phenomenon of new technology being locked out of the marketplace by old technology and old technology being locked in is well understood (Arthur 1989) and can be dealt with within the framework of existing institutional arrangements and without recourse to general reform and restructuring of incentives. Neither is it altogether unusual to see technology development as inseparable from the cultural and structural setting in which the technology will be used and with which it must be compatible if it is to be accepted and successful.

ical changes. Until now this 'trinity' has not been sufficiently emphasised in the whole debate surrounding sustainable prosperity. It is usual to talk only about technology or behaviour or the market and its legal framework. This gives a distorted picture. If our goal is sustainable prosperity, there needs to be a co-evolutionary development of all three: culture, structure and technology. Any debate that treats only one of these in isolation and stresses that change in any one offers a panacea is misguided. This type of debate, which is common, is by definition abstract in the extreme. Matters such as which absolutely basic needs have to be met and what risk society is prepared to take have always been debated. But it is difficult to achieve consensus on such matters if they are debated in the abstract. The danger is that abstract discussion goes round in circles. In order to move the debate on it must be made more concrete. If we can come up with a technological design or a prototype, the debate can become more meaningful. We can test the design and clarify the costs and benefits and risks. We can ask what societal and economic conditions must be met before the technology can be implemented. A technological design of this sort should not be produced by R&D scientists working alone in a laboratory; rather, it should be the result of a continuous consultation with society.

6 Such as would be implied by a reform of taxes, subsidies and government programmes and a shift toward full-cost pricing.

This basic philosophy is embedded within techniques for technology development such as Constructive Technology Assessment (CTA) that already form part of technology management practice in some situations. However, the conventional reason for lock-in and lock-out has to do mostly with the different positions of old and new technologies on their respective learning and cost-reduction curves, the cost advantage to established technologies represented by the Salter cycle,[7] the advantage to old technologies of sunk capital investment in infrastructures that is already written off and barriers to market entry raised against new technologies by organised interests vested in the old. All of these relate to the relative strength of old and new technologies in the everyday struggles that occur between them within the framework of prevailing incentives.

In respect to sustainable technologies, there is a different—more correctly, an additional—phenomenon. This is the likelihood that sustainable technologies might never be cost-competitive under prevailing incentives in distorted markets and that, to become economically viable, they ultimately depend on fundamental cultural, structural and economic reform. All markets are socially constructed and markets are subject to potential reconstruction by societies and their representatives to achieve societal objectives. Nonetheless, this dependence of sustainable technology on market reconstruction makes this a very special and intractable Catch 22. It urges new approaches for dealing with the dilemma that it represents. It also places special emphasis on finding new co-evolutionary ways of integrating dynamic and futuristic cultural and structural considerations into the dynamics of technology development. The likely views and behaviours of future generations—future citizens unable to represent themselves—must somehow be represented, considered and integrated within technology designs.

Two other aspects make this case particularly special. The first is the long lead-times involved in developing sustainable technologies that depend on such systemic or 'paradigmatic' change. Past commercial applications of fundamentally new technologies—such as television, lasers and photo-optic cables—show that the typical innovation process takes 30–50 years. Even though there is evidence that this time-span is contracting, it is unrealistic to expect it to be much less for sustainable technologies, which, as just noted, depend on paradigmatic change. Moreover, the time taken before commercialisation is sufficiently developed for a sustainable technology to make a difference to environmental stress could be even longer, since this depends on the rate of diffusion of the technology and achieving a penetration into markets sufficient to displace eco-inefficient technologies. Thus, there is no time to lose if sustainable technologies are to be ready in time to hold

7 The Salter cycle is a 'virtuous cycle' of self-sustaining and self-reinforcing cost reduction. As experience with a product increases, production costs reduce, which allows the price of the product to fall. This increases the demand for the product allowing economies of scale to be reaped in production and further learning, etc.

back the surge in environmental stress that population and economic growth will otherwise bring by the mid-21st century. Another implication of long lead-times is that failure to take advanced action to develop sustainable technologies could leave businesses and nations ill-placed to respond to future price changes and shortages of eco-capacity, which will not automatically be signalled by price trends in advance.

Market distortions—in the form of externalised costs, taxation structures, patterns of subsidy, exaggerated discount rates and perverse accounting procedures—already prevent price signals from reacting smoothly to developing factor shortages and surpluses. These distortions particularly affect factor markets and environmental resources. The important aspect is that there are potentially significant advantages for both nations and businesses in pre-empting resource shortages and price changes that are predictable even if not yet signalled in price trends. In the event of an increasing scarcity of eco-capacity, which world population and economic growth seem to make inevitable, costs for nations and businesses highly dependent on environmental resource use will soar. By incorporating resource scarcity into new technology designs from scratch, eco-efficiency can be achieved more cheaply and effectively than by improving existing technology incrementally. A longer lead-time should lower the cost to business of preparing responses and lead to more robust, better-designed and better-tested technologies, more attractive products, and better-prepared strategies for meeting consumer needs. With increasing scarcity of eco-capacity, eco-efficiency will become a critical element in competitiveness. The latent demand for eco-efficient goods and services will create new business opportunities and open new markets. Nations and companies best prepared will be leaders in these new markets.[8]

The second aspect lies in the contradiction that technology, while a pivotal enabling factor in sustainability, is widely mistrusted as a means of solving complex societal problems. Reaction by society against technological 'fixes' is well known, but has recently been hardened by the clear role of technology in contributing to environmental and human health problems, including those related to (un)sustainability. People are cautious about using technology to solve problems perceived as outcomes from earlier technological innovation. Past technology and past innovation processes have proved fallible. Many negative outcomes of earlier innovations were unforeseen. This is widely construed as ominous. Concern is further sensitised by the intrinsic risks and uncertainties that surround new

8 Other advantages include: for companies, the opportunity to improve standing and image among customers, employees, business associates, shareholders and local communities; for nations and companies, the possibility of reducing exposure to resource price and supply insecurities (especially those prone to forces outside their control); and, for nations, the chance to provide higher levels of environmental and risk protection for citizens and to increase the real productivity of national economies by improvements in efficiency and self-sufficiency (Weaver 1997).

technologies[9] and by people's fear of having technologies imposed upon them and becoming unknowing parties to technological 'experiments'.[10] Rapid advances in basic scientific knowledge—in energy and materials sciences, information technology, computing, flexible engineering, robotics, biotechnology, genetics, medical sciences and nanotechnology—raise further sensitivities because of the difficult moral and ethical issues to which they give rise.

THE SPECIAL SITUATION OF THE NETHERLANDS

Solving these dilemmas is important for all societies, but it is especially important for those whose production and consumption patterns impose higher-than-average demands on eco-capacity, both local and 'sequestered' from abroad. It is especially important also for societies vulnerable to the environmental and economic consequences of either a reduction in eco-capacity or reduced access to environmental resources. The Netherlands falls into both of these categories. The Netherlands is a highly developed, highly industrialised society. In relation to its small land area (3.4 million hectares), it has both a large economy (a GNP of around US$350 billion) and a large population (15 million). This gives the Netherlands one of the highest population densities in the world (around 4.5 persons per hectare) and a high income per capita (around US$23,000), providing a high material welfare. The economic status of the Netherlands is currently made possible by an intensive economy backed by high volumes of import, export, transport and value-adding industry. Much of this industry is based on adding value to imported materials and feedstocks before these are re-exported. This is the basis, for example of the petrochemicals, metallurgical and food-processing industries. Thus, for example, the Netherlands, with one of the smallest land areas of all countries, emerges as one of the most important actors in world food trade, importing low-value feeds, mostly from the Far East, and exporting high-value meat proteins, mostly to European neighbours.

The Netherlands' main port at Rotterdam is Europe's largest and busiest. The Netherlands also has one of the highest densities of motorway network in the world (5.5 km/100 km^2). Levels of both private and commercial vehicle ownership and use are high and still growing. The Netherlands has one of the world's highest per capita energy productions and consumptions (200 GJ/capita) and CO_2 emissions

9 Concern is particularly acute in respect to the human food chain and genetically engineered foods.

10 For example, if decisions are taken 'over the heads' of people or if market choices and information on these is insufficient.

per capita (9.16 tonnes/capita). Its level of pork production is among the world's highest. With 14 million pigs, the Netherlands has the world's highest density of pigs (4.1 pigs per hectare) and, also, of pig waste. These activities impose high demands on eco-capacity, both at home and sequestered from abroad. A recent study (Adriaanse *et al.* 1997) estimates the total materials requirement of the Dutch economy to be 1.275 billion tonnes per annum. This equates to 378 tonnes per hectare per year or 84 tonnes per person per year or 3.2 tonnes for each US$1,000 of GNP.

Although currently energy self-sufficient owing to natural gas production in the North Sea and the export of gas sufficient to offset its own use of imported oil, the North Sea gas fields are declining and are expected to be exhausted within the next decades. The Netherlands also faces problems with waste generation and pollution. The pig waste problem typifies a general problem: wastes and pollutants from all the value-adding activities based on imported feedstocks are left behind when the final products are exported. The small land area of the Netherlands, the flat terrain, the high water table and the density of the drainage network compound this problem. Water-borne wastes are rapidly diffused but are only slowly transported away. Furthermore, a key finding from the study of material flows is that more than 70% of the total material requirement that supports the Dutch economy arises outside the nation's borders. This implies that more than US$200 billion of presently generated Dutch GDP depends directly on using eco-capacity that may not, in the future, be available to the Dutch economy.

These statistics demonstrate that a future shortage of eco-capacity has serious implications for the Dutch economy as well as for the environment. The Netherlands already has an established role and reputation in respect to major industries and activities such as food production, chemical production, transportation and port activity. These activities are staples of the Dutch economy. Shortages of eco-capacity threaten to limit not only the output of useful goods and services from these sectors, but also the future stream of economic and social benefits that they contribute today to GNP, tax revenues, employment, export earnings and welfare. If these sectors are to continue to make comparable future contributions to the wellbeing of the Dutch economy and society, they must be restructured so that they make much more efficient use of available eco-capacity. This depends on innovation and on R&D to provide the basis for the necessary changes in technology, structure and culture. Research priorities for sustainable technology have to be determined from a broad-based definition of 'needs' that embraces a full appreciation of what is at stake in the event of future shortage of eco-capacity, including the threat that it poses to established benefits deriving from value-adding activities and sectors that are unsustainable at present. The need is not only for technological substitutes that will meet ecological criteria and maintain future flows of goods and services, but that will also maintain income, jobs, tax revenues and other indirect benefits that flow today from unsustainable technologies.

INNOVATION FOR TECHNOLOGY RENEWAL

In summary, although not sufficient, the role of technology is pivotal for providing assurance that an acceptable transition to sustainability is feasible. But the interdependence between technological, cultural and structural change effectively blocks progress on all fronts. Strategic, systems-oriented, sustainable technologies have long lead-times and innovation horizons that are uncertain and conditional. Though needed, such technologies will not be developed automatically. Yet failure to develop sustainable technologies reduces the possibility of ever achieving transition to sustainability and of minimising transition costs in the eco-restructuring process. It also threatens the loss of opportunities that are contingent on eco-efficiency, such as to win market share and political say in the new world context that a shortage of eco-capacity and its interaction with other ongoing changes will bring. These other dynamics include globalisation, integration, liberalisation and shifts in the global distribution of economic and political power.

Sustainable technologies will need to be developed in a co-evolutionary way that integrates societal concerns into technology designs as well as building constituencies in their support and in support of the necessary restructuring of incentives and behaviours. This development must be sensitive to the mistrust of society for technological fixes, to the acute unsustainability of present arrangements, and to the need to develop technological replacements capable of fulfilling multiple roles. Beyond providing services to consumers, these roles include the positive contributions made by the technologies and activities to domestic product, the trade balance, tax revenues, employment and the transfer of skills and information across generations. Replacements for technologies that are to be phased out or scaled down on grounds of unsustainability must be capable of addressing multiple needs by fulfilling multiple functions. Such technologies will not come about through incremental improvement of existing technologies, nor will they come about without a conscious, concerted and focused effort on the part of government, business and societal groups to tackle the issue strategically and systematically. Above all, the effort depends on innovation in regard to the innovation process itself. Effectively, this forms the case for and background to the Dutch STD programme: a research and support activity aimed at strengthening innovation capacities for the development and diffusion of long-term sustainable technologies.

The remainder of this book constitutes a review and evaluation of the programme. In Chapter 2, we look in more detail at the scale of the challenge that sustainability poses for technology development and at how this challenge was translated into quantitative, operational targets appropriate for the Dutch context by Weterings and Opschoor for the STD programme. Chapter 3 looks at the past record of technology development, innovation and diffusion and draws lessons for the design of a programme aimed at strengthening innovation capacities and improving the prospects of a co-evolutionary restructuring of development pathways toward more sustainable production–consumption systems, involving sustainable technologies and sustainable use of technologies. Finally, in this opening section of the book, Chapter 4 moves from a discussion of the underpinning theory and philosophical approach of the STD programme to a description of its working method, the tools it used and its case-study illustration projects. The remainder of the book provides detailed descriptions of the case studies (Part 2) and an analysis of the programme experiences and achievements which brings out transferable lessons and recommendations for future work (Part 3).