The Management of the Co-Evolution of Technical, Environmental and Social Systems

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1. Introduction

Environmental problems of pollution have been countered quite successfully through the use of control technology and cleaner processes at the production side. At the consumer side little has changed. People still engage in the individual use of motorised transport and energy-intensive life styles. The common explanation for this is that people *want* automobility, cheap energy and cheap food. Such an explanation assumes that people preferences are fixed and that the system is geared toward satisfying these. It fails to see that people want many things; that consumer choices are restricted by supply choices, and that user benefits may conflict with societal benefits. Supply and demand not only interact but also interlock. Their interaction gives rise to particular trajectories, which are sustained by industrial interests vested in it, assumptions about user needs and high costs of making a system change, both for the actors concerned and society of large. The above helps to understand why most change is incremental, aimed at exploitation rather than exploration (March 1991).

Environmental policy has been unsuccessful in changing behaviour and bringing about societal transformations, involving a change in both technology and behaviour. There is a consensus that the existing trajectories in transport, energy, and agriculture are not sustainable, but the alternatives are not clear or deemed unsatisfactory by experts. There is a conflict between short-term goals of policy and the long-term change needed for sustainability. Whilst the goal of sustainable development has been accepted there is a paucity of concepts and tools to work towards it. This paper offers an approach to further sustainability goals. We have called this approach transition management because it aims at managing the processes of co-evolution that make up a transition. Transition management consists of the management of phases of a transition in a reflexive, iterative and stepwise manner. Dutch policy makers in the new national environmental policy plan *Een wereld en een wil* (A world and a willing) have embraced it and made it official policy. The plan uses 2030 as a time horizon. In this paper we explain the notion of transition management and explain why it is a useful model for managing processes of co-evolution and transitions.

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[1] The paper draws on joint work of the authors with Marjolein van Asselt, Frank Geels, Geert Verbong and Kirsten Molendijk for the 4th Dutch National Environmental Policy plan (NMP-4).

2. The Need for Transformation or System Innovation

The accumulation of stock pollutants and ever-increasing scale of economic activity, undoing environmental improvements per unit of output, call for system innovation. End-of-pipe solutions and other types of changes at the supply side will not suffice. We need more comprehensive responses, involving a change in production chains, in product-service systems, and the ways in which we consume and live (Kemp and Soete 1992; Kemp 1995; Weterings et al. 1997; Weaver et al. 1999; Vellinga and Herb 1999; Ashford et al. 2001). In the vocabulary of innovation studies, we need system innovation besides system improvement. System innovation in the sociotechnical realm involves changes in sociotechnical systems beyond a change in (technical) components. It is associated with new linkages, new knowledge, different rules and roles, a new 'logic of appropriateness', and sometimes new organisations.[2] System innovation usually consists of a combination of new and old components and may even consist of a novel combination of old components, as in the case of industrial ecology – the closing of material streams through the use of waste output from one company by another.

Two other examples of system innovation offering environmental benefits are: the hydrogen economy (with the hydrogen generated in clean ways, for instance through the use of renewables); and integrated mobility (or chain mobility). In the latter case, people are using different transport modes (collective ones and individual ones such as a car and bicycle) using information services from mobility agencies that offer them travel plans and make reservations. Chain mobility involves a wide range of changes, in infrastructure (in the form of P+R stations and special bus lanes), in technology (such as light rail in conurbations) but also an array of social and organisational changes: the collective ownership and use of cars (car-sharing and riding), the creation of mobility agencies offering and selling intermodal transport services, the integration of collective transport schemes, and the introduction of transport management system for employees by companies.[3]

System innovation transcends a single country or a single continent and goes beyond the use of more efficient manufacturing processes and green products (Vellinga and Herb 1999). The transformation may be beyond those that the dominant industries and firms are capable of developing easily, at least by themselves (Ashford et al. 2001). The time scale for system innovation, one generation or more, is long from a policy point of view. An indication of the time scale and geographic scale of system innovation (vis-à-vis the scales for other types of change) is given in figure 1.

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2 A related distinction is that between sustaining innovations and disrupting innovation (Christensen, 2000).

3 Three other examples, described in Ashford et al. (2001) are: biomass-based chemistry, multiple sustainable land-use (the integration of the agricultural function with other functions in rural areas) and flexible, modular manufactured construction.

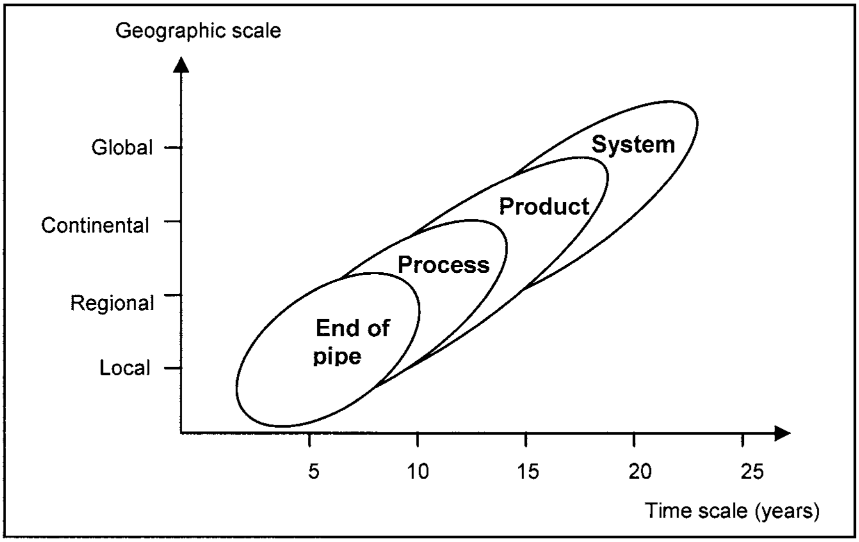

Fig. 1. The time Scale and Geographic Scale of Societal Responses to the Issue of Environment. Vellinga and Herb 1999

System innovation may consist of the development of a new system (such as the development of the grid-based electric system) and the transformation of an existing system, such as the emergence of a regime of chain mobility out of the existing regimes of individual and public transport.

The distinction between system innovation and system optimisation is useful because it forces one to think about the long-term consequences of innovations: whether they give rise to or contribute to system innovation or do not alter the current path of development. An example of such a mapping of innovations (and corresponding policy measures) is provided in Figure 2.

Figure 2 depicts whether the innovations and policy measures to counteract transport problems contribute to system optimization or to system innovation. Personalized public transport such as dial-a-ride services and CO_2 policies are believed to contribute to system innovation in the form of chain mobility with people combining individual means of transport and collective means for their travel needs. Anti-congestion policies are believed to sustain the current trajectory of motorized passenger transport based on the individual use of cars. Some innovations may be part of system optimization and of system innovation. An example is urban cars, which may be used in combination with collective forms of transport or as a 2nd or 3rd household car. The fact that innovations may be used both within an existing system and within a new system is not uncommon for innovations. Such innovations may be called *two-world* innovations and may play an important bridging function within a transition, together with hybrid technologies (Geels and Kemp 2000).

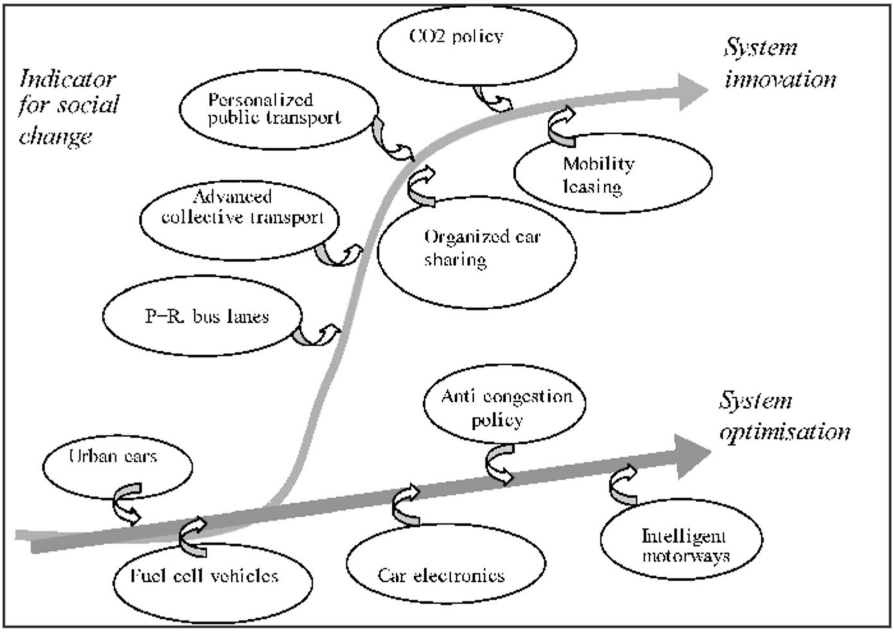

Fig. 2. Systemoptimazation versus System Innovations in Land-based Passenger Transport

3. Transition and Co-Evolution

For the purposes of managing change processes to sustainability it is useful to use the concept of a *transition* rather than system innovation because it brings into focus four things:

1. The end state (new equilibrium);
2. The path towards the end state, made up of different stages;
3. The transition problems that dog the transition process;
4. The wide range of developments internal and external to a particular system that shape the outcomes.

A transition is the confluence of developments that span various systems and domains. A transition consists of a set of connected changes in technology, the economy, institutions, behaviour, culture, ecology and belief systems that reinforce each other. Within a transition there is multiple causality and co-evolution of independent developments (Rotmans et al. 2000, 2001)

Although transitions are characterized by non-linear behaviour, the process itself is a gradual one. The nature and speed of change differs within each of the four stages (see figure 3):

In the *predevelopment* phase there is very little visible change but there is a lot of experimentation

- In the *take-off* phase the process of change gets under way and the state of the system begins to shift.
- In the *acceleration* (breakthrough) phase structural changes take place in a visible way through an accumulation of socio-cultural, economic, ecological and institutional changes that react to each other; during the acceleration phase, there are collective learning processes, diffusion and embedding processes.
- In the *stabilisation* phase the speed of social change decreases and a new dynamic equilibrium is reached.

During a transition there are changes in:

- The speed of change;
- The size of change; and
- The time period of change

Being the three system dimensions of a transition.[4]

It should be noted that the concepts of speed and acceleration are relative. All transitions contain periods of slow and fast development, caused by processes of positive and negative feedback. Within a transition there are no great jumps and it does not occur quickly. A transition consists of a gradual, mostly continuous process typically spanning at least one generation (25 years). This can be accelerated by unexpected or one-time events, for example, war, large accidents (e.g. Chernobyl) or an oil crisis, but not be caused by such single events.

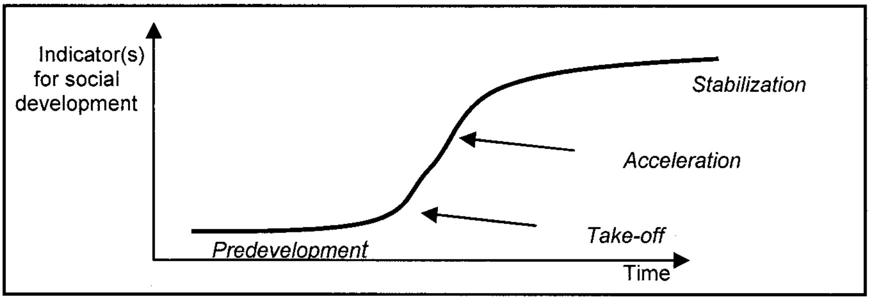

Fig. 3. Four Phases of Transition, Rotmans et al. 2000, 2001

Transitions involve structural change but not everything changes. What changes most fundamentally are the assumptions, practices and rules. Technological changes may be secondary, which is a different way of looking at transitions than most people do; especially engineers are inclined to view technology changes as

[4] The *nature* of change can be viewed as a fourth dimension.

primary, and institutional changes as secondary, which are often seen as being forced by technology, overlooking the fact that the technologies are made by people guided by new ideas, a new outlook and a new set of assumptions.

A transition

... is the shift from an initial dynamic equilibrium to a new dynamic equilibrium

... is characterised by fast and slow developments as a result of interacting processes

... involves innovation in an important part of a societal subsystem

A transition is the result of long-term developments in stocks and short-term developments in flows (Figure 4).

Since stocks change slowly, the dynamic pathway of a transition is characterized by an S curve (for example a logistic curve). The developments occur in various domains: technology, economy, social life, culture, nature. Every domain has its own dynamics. Cultures only change slowly, just like ecological systems. Economic changes, may occur very rapidly, price fluctuation being an example. Institutional and technological changes are somewhere in between. The whole picture, therefore, forms a hybrid mixture of fast and slow dynamics. The various time axes shift over each other and constantly influence each other. The slowest processes to a great extent, determine the tempo and the direction of the entire dynamics, i.e. by the developments in stocks.

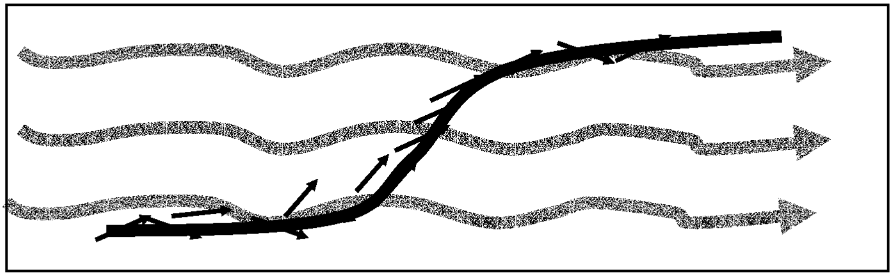

Fig. 4. A Transition is the Result of Long-term Developments in Stocks and Short-term Developments in Flows, Rotmans et al. 2000, 2001

The concept of transition can be used at different aggregation levels. When analysing sociotechnical systems, it is useful to use the multilevel scheme of Rip and Kemp (1998), which makes a distinction between niches, regimes and the sociotechnical landscape. The advantage of this scheme is that it is not based on a concentric view, with the existing system in the middle, but pays attention to the wider context and the dynamics in it: the evolution of macro-variables such as globalization, the evolution of prices and incomes, political changes, changes in policy belief systems and values, regime changes and microscopic changes: the development and use of new technologies in niches, local initiatives, leading to social learning processes that in due course may transform an existing system.

We can't go much deeply into this scheme. For those interested in it we refer to Rip and Kemp (1998) and to Kemp and Geels (2000). An important level is the meso level of *regimes*. A regime refers to the dominant practices, rules and shared assumptions that guide private action and public policy in a field, structuring the behaviour of actors which tend to be geared towards optimizing the system rather than transformation. The distinction between niches, regimes and sociotechnical landscape helps to understand change processes, for example why radical innovations often come from outsiders: because the regime actors are locked into old ways of thinking and old technologies, which leads them to improve existing technologies and strategic action to fight off a new development. But once the regime rules change – for example when regime actors start to see a new development as an opportunity rather than a threat – a reversal of strategy may occur; the regime actors may give a new development momentum through the application of large amounts of capital and organizational and marketing power. When this happens, that is when the mental models that guide key actors change, new developments get momentum and things may change very rapidly.

Niches are the local domains in which new or non-standard technologies are used. The niches may be market niches or technological niches, protected places. Military demand often afforded a niche for radical technologies. Companies may also create a niche for new products for strategic reasons, as a springboard to mass markets (Lynn et al. 1997), but niches may be created by all kind of actors or simply be the result of the heterogeneity of demand and local circumstances.

The third level is the macro level of the *sociotechnical landscape*. This relates to background variables such as the material infrastructure, political culture and coalitions, social values, worldviews and paradigms, the macro economy, demography and the natural environment, which channel transition processes, and change themselves slowly in an autonomous way. The term landscape refers to the lay of the land with its gradients. The macro landscape channels both micro and meso developments. In imagery terms, changes in worldviews (belief systems) and macro policies (such as agreements in WTO rounds or CFC control policy) may rain down upon the macro landscape, but its contours still dictate their convergence into rivers (figure 5).

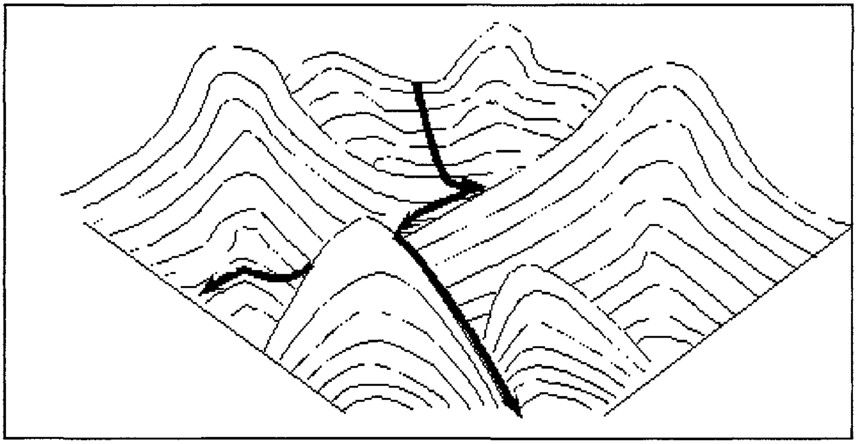

Fig. 5. The Macro Landscape Channels Micro and Meso Developments (from Sahal 1985)

4. Policy Programmes for System Innovation

After the reliance on end-of-pipe solutions and clean technology to deal with environmental problems, some countries have accepted the need for transformation of functional systems (especially agriculture, but also transport and energy). The Netherlands is such a country, acting as a forerunner. The term system innovation is used as a policy concept and several policies exist for it. Before we turn to transition management it is useful to describe these policy initiatives, focussing on what is missing in the programmes. The policy initiatives are: the DTO programme (a research programme for sustainable technologies), the white paper Environment and Economy, NIDO and EET.

DTO is an interdepartmental research programme for sustainable technologies, which ran from 1993-1997. The goal of the programme was to identify and work towards technology options offering a factor 20 environmental efficiency improvements in broad areas of need such as nutrition, transport, housing, and water supply and protection. Industry was an important actor in the programme. Industrial opinion leaders were asked to think about long-term technological solutions offering magnitude environmental benefits. They were selected for their imagination and their position within industry, because the programme wanted to influence the industrial research agenda. Many of the industry people were research directors. In total 25 million guilders (11.3 mln €) was spent under the programme by the Dutch government. The financial contribution from industry was low, about 10% of the costs of the illustration projects, in the form of money and time. The DTO programme led to the development and articulation of 14 illustration processes for sustainability. The 14 illustration processes were:

- Sustainable multifunctional land use (nutrition)
- High-tech agro production (nutrition)
- Integrated crops utilisation (nutrition)
- Novel protein foods (nutrition)
- Underground tube systems for transport (transport)
- Automatic demand and supply management of transport streams (transport)
- Hybrid electric propulsion (transport)
- Fuel cells in mobile applications (transport)
- Mainport Rotterdam (transport)
- Sustainable village renewal (housing)
- Sustainable office building (housing)
- Sustainable chemistry (chemistry)
- Integrated water chains (water)
- Sustainable washing (water)

The project was successful in tapping people's mind and imagination and led to ideas for system innovation and networks of collaboration but failed to influence industries' research agenda in an important way for the reason that the technologies were far from economical. Their use would require a change in the frame conditions giving the sustainable technologies a competitive edge. A 5 million guilder (2.3 mln €) programme of knowledge transfer called DTO-KOV followed the programme but like the original programme this programme did not address the root problem of unfavourable frame conditions. The absence of a pull mechanism frustrated the further development of these technologies and the occurrence of processes of co-evolution resulting in transformations and the creation of new systems.

The second policy initiative is a government white paper about the role of technology in environmental policy. The paper called Environment and Economy came out in 1997 and contained a large number of examples of system innovation offering environmental benefits together with private user benefits. The paper articulated the policy belief that economic growth and environmental protection can be reconciled through the use of innovative technology. It made a call upon localized actors, market actors and local government, to develop these options. An evaluation of the paper and the initiatives in its wake by the CPB said that the paper was successful in giving a sense of direction through the use of 'figureheads' (boegbeelden) but that one also needs generic policies that internalize the environmental costs.

The 3rd initiative is the EET programme, a research programme for breakthrough innovations offering economic and environmental benefits in a time space of 5-20 years.[5] So far 70 projects have been funded (plus 38 KIEM projects, technical feasibility studies). An average EET project has a size of 8 million guilders (3.6 million €) of which half is funded by the government (Willems and van den Wildenberg 2000). The minimal size is 1 mln guilders (0.45 mln €). The total size

[5] EET stands for Economie, Ecologie, Technologie.

of the EET projects funded since its start in 1995 is 529 million guilders of which the government paid 280 million guilders. It is a very large and perhaps unique subsidy programme through its focus on both economic and environmental benefits.

EET complements environmental technology programmes that have a more narrow focus on environmental benefits and that offer little opportunities for system innovation. The focus on radical innovation is good, given the long development times for such innovation and positive spillover effects. A less good aspect of it is that little attention is given to the societal boundary conditions that are needed for the use of the innovations that are under development: the price of energy, whether a energy tax is needed for its use (many projects aim to develop energy efficient innovations), the systems aspects (of complementary technology, infrastructure, skills and so on needed for its use) and the social acceptability. Applicants could have been asked to think about and write about in the application. The programme and selection of projects could also have been linked to transition agendas and to road maps made by industrial actors. As it stands, the EET programme is not really aligned with environmental policy and oriented towards one aspect of system innovation: which is technology.

NIDO (Nationaal Initiatief Duurzame Ontwikkeling) is a programme which for a period of two years supports 'jump projects', initiatives which offer sustainability benefits. It is less technology focused than DTO and EET and more oriented towards practical implementation. The NIDO budget for 2001 is 8.5 million guilders (3.9 million €), which is used to support 4 programmes: *van financieel naar duurzaam rendement about* the coupling of companies' financial performance indicators with companies' ecological and social performance indicators; *duurzame logistiek* which is about sustainable logistic chains; *wonen, leven, werken* about sustainable living and livings, and *waarden van water* about integrated and sustainable urban water management. The private contribution to these projects is 3.5 million guilders (1.6 million €). Apart from supporting the programmes financially NIDO helps participating parties with obtaining additional funds and the dissemination of knowledge. The small size of the projects and short period of support means that for some type of changes (such as the shift to an emission-low energy system or a different type of transport systems) the support from NIDO will be too little to have much of an impact. Like the other programmes, NIDO does not deal with the overall frame conditions. It does explore visions for system innovation.

5. Transition Management

The experiences with the above Dutch programmes (especially DTO) led Dutch policy makers to look for a more integrated and comprehensive approach to work towards transitions. They asked the authors of this chapter to analyse the possibilities for managing transitions, and to come up with a model for transition management. The below model is the result of this project in which we worked in close interaction with the working group responsible for the 4th National Environmental

Policy plan (NMP-4) and a larger group of policy officials.[6] Several considerations informed the model. The most important of these were:

- The need to orient myopia of actors, both business actors and government actors, towards the future and to societal goals;
- The existence of barriers to system innovation, having to do with interests, costs, beliefs and standard assumptions favouring incremental change;
- The need for coordination of fragmented policy fields: Science & Technology policy, economic policy, innovation policy, environmental policy, transport policy and agriculture policy, all of which have a role to play in the transition to a low-emission energy system;
- The need for legitimising policies towards structural change and democratically setting goals;
- The need for opting for an approach of gradual change and learning about a variety of options;
- The need for flexibility both with respect to the goals and paths towards the goals.

Transition management consists of a deliberate attempt to bring about structural change in a stepwise manner. It does not attempt to achieve a particular transition goal at all cost but tries to utilise existing dynamics and orient these dynamics to transition goals that are chosen by society. The goals and policies to further the goals are not set into stone but constantly assessed and periodically adjusted in development rounds.[7] Existing and possible policy actions are evaluated against two criteria: first, the immediate contribution to policy goals (for example in terms of kilotons of CO2 reduction and reduced vulnerability through climate change adaptation measures), and second, the contribution of the policies to the overall transition process. Policies thus have a *content goal* and a *process goal*. Learning, maintaining variety and institutional change are important policy aims and policy goals are used as means. The use of development rounds brings flexibility to the process, without losing a long-term focus.
A schematic view of transition management is given in figure 6.

6 The project team consisted of Jan Rotmans, Marjolein van Asselt and Kirsten Molendijk from ICIS, René Kemp from MERIT, Frank Geels from the University of Twente and Geert Verbong from TUE.

7 The idea of development rounds comes from Teisman (2000).

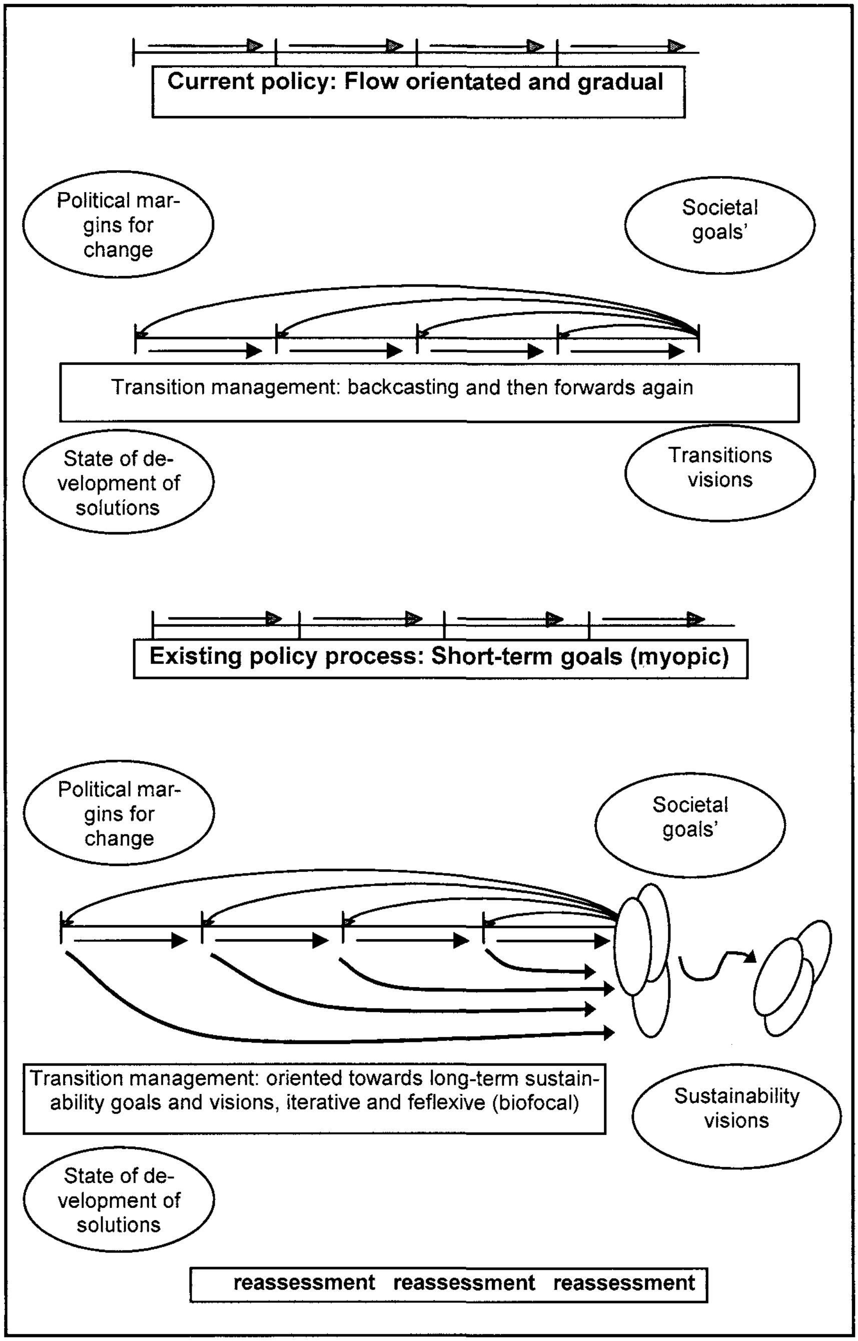

Fig. 6. Short-term versus Long-term Policy

Transition management is based on a two-pronged strategy. It is oriented towards both system improvement (improvement of an existing trajectory) and system innovation (representing a new trajectory of development or transformation). The role of government differs per transition phase. For example, in the predevelopment stages there is a need for social experimentation and creating support for a transition programme, the details of which should evolve with experience. In the acceleration phase there is a special need for controlling the side effects of large-scale application of new technologies. Throughout the entire transition the external costs of technologies should be reflected in prices. The changing nature of policy is shown in figure 7.

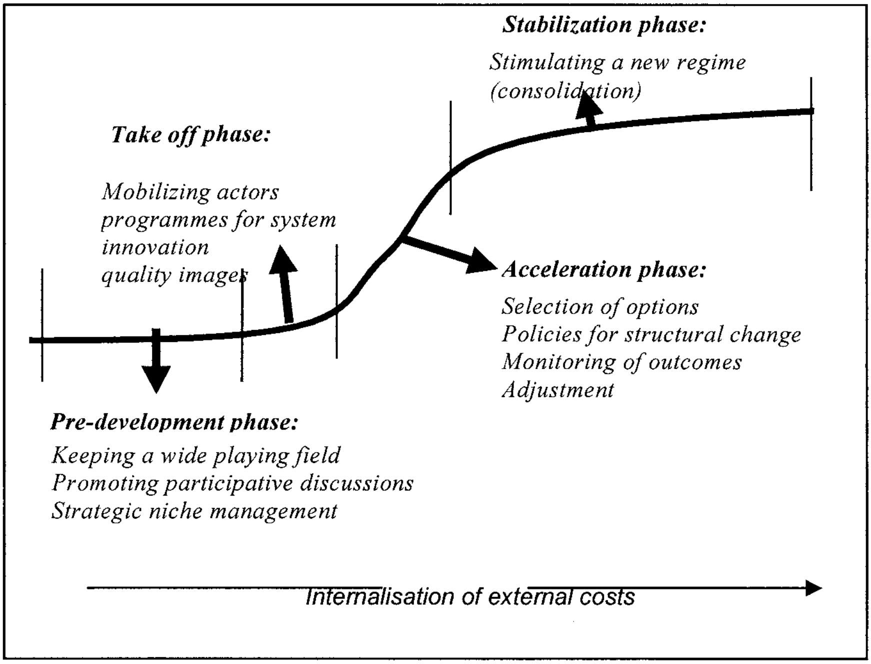

Fig. 7. Role of the Government in various Phases of a Transition Process[8]

Transition management breaks with the planning and implementation model and policies aimed at achieving particular outcomes. It is based on a different, more process-oriented philosophy. This helps to deal with complexity and uncertainty in a constructive way. Transition management is a form of process management

8 Strategic niche management is the creation and management of a niche for an innovation with the aim of promoting processes of co-evolution. The innovation is used by real users. This helps to promote interactive learning (between suppliers and users) and helps to build product constituencies (which include policy actors). The approach of SNM is described in Kemp et al. (1998a), Kemp et al. (1998b), Kemp et al. (2001) and Hoogma et al. (2001).

against a set of goals set by society whose problem solving capabilities are mobilised and translated into a transition programme, which is legitimised through the political process.

Key elements of transition management are:

- Long-term thinking (at least 25 years) as a framework for shaping short-term policy
- Thinking in terms of more than one domain (multi-domain) and different actors (multi-actor) at different scale levels (multi-level); how developments at one level with one type of actors gel with developments in other domains
- A focus on learning and a special learning philosophy (learning-by-doing and doing-by-learning)
- An orientation towards system innovation
- Learning about a variety of options (which requires a wide playing field).

Transition management does not aim to realize a particular path. It may be enough to improve existing systems, it may also be that the problems turn out to be less severe than at first thought.

Transition management is not an instrumental activity. The actual policies are the outcome of political negotiations and processes of co-evolution which inform further steps, but the basis steps are:

The transition goal

This consists of a basket of images, not a societal blueprint. The transition goal is multi-dimensional and should not be defined in a narrowly technological sense. The goals should be democratically chosen and based on integrated risk analysis.

This will constitute a radical break with current practice in environmental policy where quantitative standards are set on the basis of studies of social risk, and adjusted for political expediency. Risk-based target setting is doomed to fail when many issues are at stake and when the associated risks cannot easily be expressed in fixed, purely quantitative objectives. This holds true for climate change but also for sustainable transport.

Transition management relies on integrated risk analysis and the setting of minimum levels for certain stocks (e.g. health, ecosystem diversity and capital) and aspiration levels. The estimates of various types of risk are subjective, since the risks are surrounded by structural uncertainties, legitimating the incorporation of various perspectives (van Asselt 2000). The net result is a policy corridor for key variables, indicating the margins within which the risks are considered acceptable.[9]

The use of transition visions

Transition management is based on long-term visions that function as a framework and a frame for formulating short-term and long-term objectives and evaluating existing policy. To adumbrate transitional pathways, these visions must be

[9] The idea of a policy corridor is described and applied in Rotmans and den Elzen (1993).

appealing and imaginative and be supported by a broad range of actors. Inspiring final visions are useful for mobilizing social actors (such as 'underground transport' and 'multifunctional land use'), although they should also be realistic about innovation levels within the social subsystem in question.

The 'basket' of visions can be adjusted as a result of what has been learned by the players in the various transition experiments. The participatory transition process is thus a goal-seeking process, where both the transition goals and visions change over time. This differs from so-called 'blueprint' thinking, which operates from a fixed notion of final goals and corresponding visions.

Interim objectives

Figure 8 shows the similarities and differences between current policy-making and transition management. In each case, interim objectives are used. However, in transition management these are derived from the long-term objectives (through so-called 'backcasting'), and contain qualitative as well as semi-quantitative measures. In other words, the interim transition objectives contain *content* objectives (which at the start can look like the current policy objectives, but later will increasing appear to be different), *process* objectives (quality of the transition process, perspectives and behaviour of the actors concerned, unexpected developments) and *learning* objectives (what has been learned from the experiments carried out, have more options been kept open, re-adjusting options and learning objectives).

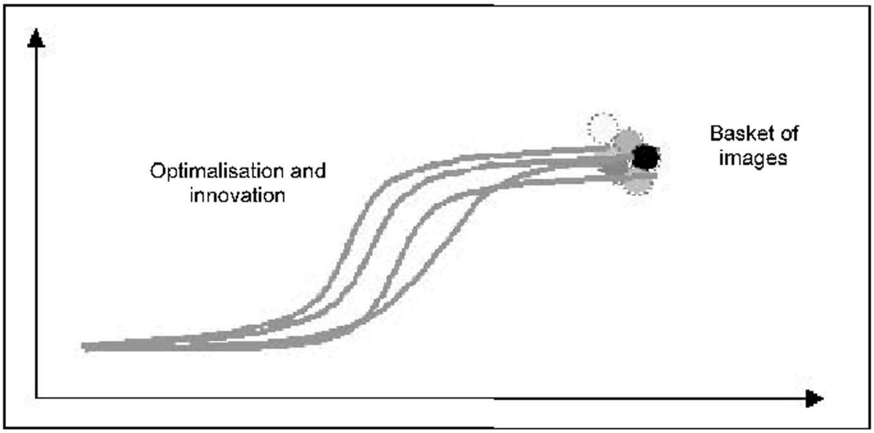

Fig. 8. Multi-dimensional Transition

Evaluating and learning

Transition management involves the use of so-called 'development rounds', where what has been achieved in terms of content, process dynamics and knowledge is evaluated. The actors who take part in the transition process evaluate in each interim round the set interim transition objectives, the transition process itself and the transition experiments.

The set interim objectives are evaluated to see whether they have been achieved; if this is not the case, they are analysed to see why not. Have there been any unexpected social developments or external factors that were not taken into account? Have the actors involved not complied with the agreements that were made?

The second aspect of the evaluation concerns the transition process itself. The set-up and implementation of the transition process is put under the microscope. How do the actors concerned experience the participation process? Is it dominated by certain parties (vested interests)? Is it too consensual (too cosy), or is there too little commitment? Are there other actors who should be involved in the transition process? Are there other forms of participation that must be tried out?

The final issue for evaluation is the amount of learning or 'enrichment' that has taken place in the previous period. A special point of attention is what has been learned from the experiments carried out to stimulate the transition. What have been the most important learning moments and experiences? Have these led to new knowledge and new circumstances? And what does this means for future policies?

Creating public support

A continuing concern is the creation and maintenance of public support. This is important for the process to keep going and preventing a backlash, which may occur when quick results do not materialize and setbacks are encountered. One way to achieve this is through participatory decision-making and the societal choice of goals. But societal support can also be created in a bottom-up manner, by engaging in experiences with technologies in areas in which there is local support. The experience may take away fears elsewhere and give proponents a weapon. With time solutions may be found for the problems that limit wider application. Education too can allay fears but real experience is probably a more effective strategy. Through the prudent use of new technologies in niches, societal opposition may be circumvented.

6. Transition Management in Relation to Current Policy

Transition management should be seen as complementing rather than conflicting with current policy. The concept of transition places short-term policy within a time frame of one, two or even three generations (25-75 years) rather than the maximum of 5-10 years, which is typical of current policy. It is also oriented towards system innovation. Unfortunately, the fruits of technical fixes will contribute more quickly to policy objectives in the short term. An example of this is CO2 collection and storage. Another example is the catalytic converter which helped to achieve reductions in automobile NOx emissions but increased energy use and that did not deal with the many social and economic problems related to car use. Technical fixes are no solution for complex social problems.

This does not mean that transition management rejects the improvement of existing systems as a route towards sustainability. It says that you must aim for both system optimisation and system innovation instead of one of the two. The two strategies are not necessary mutually exclusive: cleaner cars can go hand-in-hand with innovative public transport systems. System improvements may thus act as a stepping-stone for system innovation. Another example is organized car sharing, which facilitates intermodal travel.

A characteristic of transition management when successful is that structural change is achieved in gradually, without too much destructive friction in the form of social resistance or high costs. This is done through the use of hybrid technologies and two-world technologies and exploitation of niches, attractive domains of application. You do not need centralised comprehensive planning for the creation of a new system. It can also be achieved through in a gradual way, by adding for example new elements to an existing system, which facilitate further change.

Transition management tries to utilize the opportunities for transformation that are present in an existing system. It joins in with ongoing dynamics instead of forcing changes. Transition management also implies refraining from large-scale investment in improvement options that only fit into the existing system and which, as a result, stimulate a 'lock-in' situation.

The role of government in transition management is a plural one: facilitator-stimulator-controller-director, depending on the stage of the transition. The most effective (but least visible) is the guidance in the pre-development phase, and to a lesser extent, in the take-off phase. Much more difficult is the guidance in the acceleration phase, because the direction of development in this phase is mainly determined by reactions which reinforce (or weaken) each other and cause autonomous dynamics. It is still possible at this stage to adjust the direction of development, but it is almost impossible to reverse it.

7. The Transition to a Low-Emission Energy Infrastructure

This section applies the idea of transition management to energy supply. It examines the possibilities for managing the transition to a low-emission energy supply system. The development of a low-emission energy supply in the Netherlands makes a good case for transition management. The production, transport and distribution of energy represents an important societal sub-system, of which the services extend into social life. As with any transition, a number of important boundary conditions are set by other domains, which can either slow down or strengthen the transition. The economic domain demands affordability and sufficient economic returns; the socio-cultural domain values health, safety and asks for reliability of delivery; while from the ecological point of view, the risks for nature and the environment are important. Global and European 'landscape' developments have a major influence on the Netherlands' future energy supply.

From a transitional perspective, the transition in energy is still in its pre-development phase. The main unsustainability aspects are: the CO2 emissions contributing to climate change causing rivers overflows and increased sea levels, and the dependence on fossil fuels, making it vulnerable to price changes, which may cause economic problem but also political problems, as was demonstrated by the unrest over high diesel prices in 2000. Alternatives are expensive at their current level of development and seen as longterm options. But deferment of the transition to new energy sources only shifts the problems to later generations, because future options for the energy supply are, to a large extent, determined by current investment in R&D (IIASA-WEC). The SER, an influential advisory board in the Netherlands has stated that the energy infrastructure must change fundamentally in the long-term.

The perceived unsustainability of the existing energy system by all the policy actors and the Dutch commitment to the Kyoto protocol are drivers for change, but there are many obstacles to an actual transition. One important hindrance is the overproduction of fossil fuels, leading to low energy prices. A second obstacle are the interests of the oil companies in oil and gas, a powerful policy actor with great financial resources. Although they claim to be investing in alternative sources of energy, they fear a lock-in, and are scared of placing all their eggs in one basket (i.e. choosing the 'wrong' energy technology). As a result, the current energy producers and users causing the CO2 emissions, have no real incentive for change. Finally, there is no groundswell of popular support for a change in sources of energy. In these circumstances, how can a low-emission energy system be developed through transition management, what kind of difference does it make?

8. Energy Transition Management

An essential element of transition management is the selection of a collective transition objective. This objective needs to be multi-dimensional, and not only quantitative. From the socio-cultural viewpoint, safety and reliability of delivery are important requirements. The ecological risks might be specified in CO2 concentrations. A low-emission energy supply is often translated in terms of CO2 reductions, of the order of 50% of 1990 levels, to be realized over a period of 50 to 100 years.

The second step concerns final visions of energy transition. A recent study by the Dutch Energy Centre, ECN, articulated three visions for the future of the Dutch energy supply:

1. Status quo: In this vision the current energy infrastructure remains intact, but final energy fuels are made from renewable energy resources (solar, wind and biomass). Oil, methane and electricity remain the final energy fuels. There will be more conversion steps, particularly for biomass and coal, where the primary energy fuels are both renewable and 'clean' fossil fuels (use of fossil fuels, with storage of CO2 in empty natural gas fields or coastal seas).
2. The hydrogen economy: In this vision, hydrogen is the dominant final energy fuel, particularly for industry, transport and built-up areas. This requires a thor-

ough adaptation of the current natural gas network, so that, for example, cars are able to run on hydrogen.

3. The all-electric society: Here, the role of electricity as the final energy fuel is dominant in all sectors of society. This requires a fundamental transformation of the current energy infrastructure, including a large-scale electricity network in order to allow cars to run on electricity, for example.

These three final energy visions are not mutually exclusive, and each combines centralized with local systems of power generation. They are, however, purely technological in their perspective. Real transition final visions must have a social dimension. The social, cultural, institutional and environmental contexts of a transition must be considered carefully if the process is to attract the support of actors involved.

The ECN analysis suggests that all three final energy visions may lead to the desired 50% reduction in CO2 emissions, but only if they are followed scrupulously. The roles of renewable energy sources (solar, wind and biomass) and clean fossil fuel energy in each final vision are clear; what is not so obvious is how much all the visions continue to rely on nuclear power and the parallel development of energy-saving technology. One thing that is clear is that the biomass for energy cannot be produced in the Netherlands. To produce the biomass alone for the first vision would require the entire land of the Netherlands to be used for growing energy crops.

It is difficult to make judgements about the viability of the various options, as costs were not estimated. At first sight, the status quo final vision offers a lot of advantages, since the existing infrastructure can be preserved, although an exorbitant quantity of biomass is required. The hydrogen society final vision has the advantage that it can be entirely CO2-free. Furthermore, there is considerable enthusiasm for such advanced technology. On the other hand, such a fundamental changeover would require a great deal of time and effort. The electrical society final vision opens up the prospect of a gradual transfer to low CO2 emissions, or possibly even a CO2-free energy supply in the long-term. There is, however, not a great deal of enthusiasm for this, partly as a result of the risks (breakdowns, disasters) and the way in which it could sideline a number of innovative technologies presently in development.

Formulating interim objectives is the third step of transition management. This allows us to describe the various transition paths behind the final energy visions. Linking the chosen final energy visions to the various transition paths can outline a transition management strategy. If we look at the characteristics of an energy path, a couple of things catch the eye. Firstly, there is no one-to-one relationship between the transition path and the final transition vision. Secondly, the energy transition is not a series of jumps, but a process of gradual development.

Given the present uncertainty about which option is best, all final visions must be kept open, at least for the time being. It may take decades for a technology winner to emerge (see figure 9).

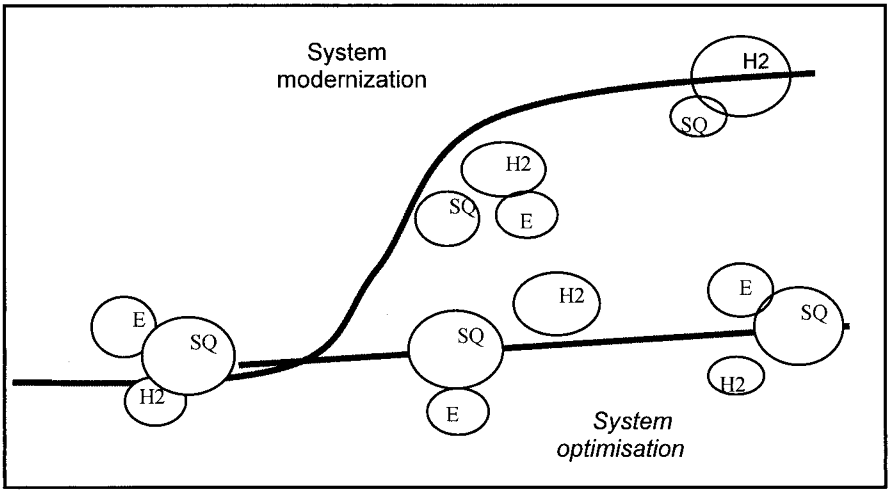

Fig. 9. Keeping open Transition Images in the Course of Time, Rotmans et al. 2000, 2001

The other options then gradually disappear from the picture, although a hybrid always remains possible. Though the rise and fall of options is evolutionary and largely autonomous, it is not outside the control of government. Even within a continuously changing economic, technological, environmental and institutional context, a strategic policy towards system innovation can refocus or redirect the transition.

The Netherlands' current policy is orientated towards observing agreements such as the Kyoto Protocol in 2010. But neither the Kyoto policy nor the proposed, tighter Kyoto+ policy is an example of energy transition management. A great deal of the CO2 reductions will be achieved abroad through low-cost options that do not contribute to system innovation.

The Netherlands could achieve CO2 reductions of approximately 13% in the period 2010-2020, according to the ECN report (making final CO2 emissions in 2020 approximately 6% lower than in 1998), but only by a Herculean effort. Unless accompanied by structural change in the energy infrastructure, it would require massive use of renewable energy and enormous investment in energy saving. Yet this seems to be the way the country is headed. With the focus on the medium term (reaching no further than 2020), there is little sign of change to the current energy infrastructure, based on oil, gas and electricity.

Not only does this reduce the time available to real change from 50 to 30 years, it effectively locks out two of the three transition visions: the hydrogen and electricity societies (see figure 10). Nothing is turned upside down, there is no forced change to the energy infrastructure. Promising alternative energy options are locked out. A transition may still be possible but one does not really prepare for it.

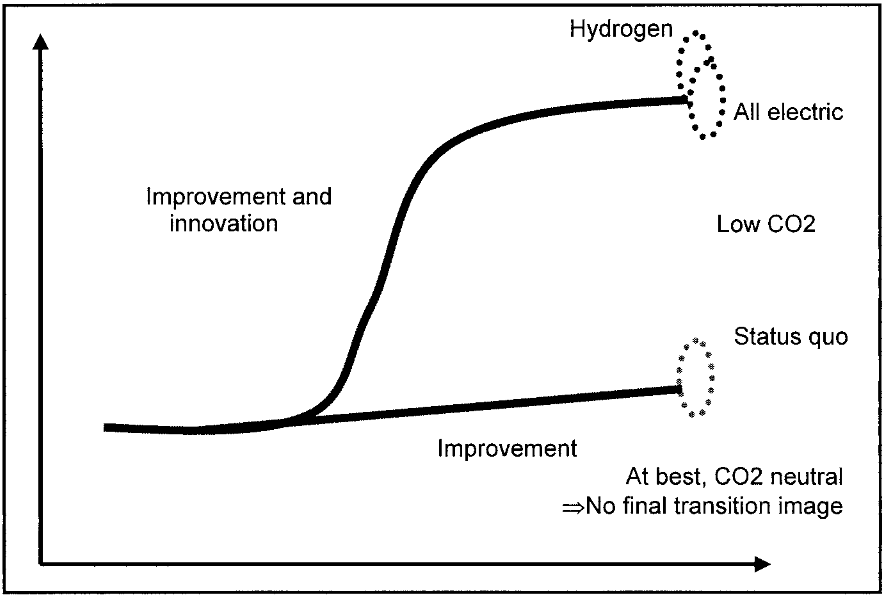

Fig. 10. Kyoto Process and the Process of System Innovation, Rotmans et al. 2000, 2001

The value of transition management is that it does not choose for one solution and also does not let time choose. Transition management does not attempt to choice the best path but attempts to learn about various options and to modulate dynamics towards societal goals. An energy transition policy contains the current climate policy, but adds three things to it: a long-term vision, an impulse for system innovation, and a framework for aligning short-term goals and policies to long-term goals.

However, our analysis also shows that it won't be easy to realise such an energy transition. Apart from the overall frame conditions that should change, it requires a double role of the government. In process terms the government has to facilitate the transition process, whereas in terms of contents, the government has to inspire the other social actors, by giving direction. The guidance for the process of a transition will require a different form of participation, however, with new actors. Via a process of so-called *niche participation*, new players who are as yet insignificant but who may become important in the future should become involved in the process. These actors may be brokers for renewable energy, communities for sustainable energy lifestyles, or producers of new energy technologies. In organizing the transition process, the government can form an interdepartmental body or create an external entity of private and public decision makers responsible for transition management. The details of this need to be further worked out.

9. Summary and Concluding Remarks

There is a convergent view that several of the present trajectories of development are not sustainable and require fundamental change. This chapter has described a method for managing the change process. We have called this method transition management because the challenge of sustainability involves the management of transition problems: the costs of adaptation, resistance of vested interests, and uncertainty about the best option. Through transitions environmental benefits may be achieved, by shifting to new systems that are inherently more environmental benign, but transitions may also produce wider sustainability benefits in the form of preservation of natural capital, health protection and social well-being.

Although transitions cannot be managed, one can work towards them. This is what transition management attempts to do. Transition management consists of a deliberate attempt to bring about structural change in a stepwise manner. It tries to utilise existing socio-technical dynamics and orient these dynamics to transition goals that are chosen by society. The goals and policies to further the goals are constantly assessed and periodically adjusted in development round. Through its focus on long term ambition and its attention to dynamics it aims to overcome the conflict between long-term ambition and short-term concerns.

> **Transition management**
>
> ... is a collective, cooperative effort to work towards a transition in a flexible, stepwide manner, utilising dynamics and visions
>
> ... involves a wide range of policies with their choice and timing gauged to the particular circumstances of a transition
>
> ... involves system innovation and system improvement

Transition management is based on a two-pronged strategy. It is oriented towards improving existing functional systems (system improvement) and towards system innovation to meet the transition goals. Policies for system innovation are adaptive and time-limeted. The role of government in transition management is a plural one: facilitator-stimulator-controller-director, depending on the stage of the transition.

The value added of transitions management is that it orients myopic actors to the future and to societal goals, that it creates societal support for a transition (resulting in a transition programme which is politically legitimised) and commits societal actors to change. It provides a basis for coordination of public and private action. It does not fix a path but explores various options.

In our view, transition management offers a promising alternative for a planning and control approach and the use of economic incentives that both suffer from serious problems: economic incentives are likely to be too weak and probably too general to promote system innovation whereas a planning and implementation approach is likely to be disruptive, by failing to include the multitude of microconcerns at the decentralized level. It is a different type of governance model, not an instrument.

Transition management involves a change in policy making, which is oriented toward long-term goals of sustainability (instead of short-term goals), to system innovation and to new actors. Transition management is not something consensual. Transition management does not exclude the use of control policies, such as the use of standards and emission trading. We need corrective policies besides push policies. The policies can be chosen and legitimised as part of the transition endeavour or independently from it. For example the use of CO2 taxes and other types of economic incentives can be legitimised by the economic principle that one should internalise external costs. The introduction of corrective policies will not be easy. Perhaps the commitment to a transition facilitates their introduction. We don't know. Perhaps it will forestall the introduction of taxes. We have to see. Transition management is not a panacea for every problem but a promising perspective. Two of ist great advantages are that it may be used to achieve a greater coherence in policy and in societal actions for sustainability and that it also is *doable* at least in a country such as the Netherlands.