Exploring Future Transition Pathways
The Socio-Technical Scenario approach

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Abstract

To achieve a sustainable energy system mere technological solutions will not suffice. It will also require changes in user practices, policy and regulation, infrastructure, networks, and institutional change. Such broad change processes are called system innovations or transitions. Such changes can be explored using scenario methods but existing methods are not well suited to tackle the variety of dimensions involved in a system innovation.

To remedy this we have developed a new scenario method called "Sociotechnical Scenarios" (STSc) that allows the exploration of the combination of technical and societal changes. In earlier work we have described a crude version of the methodology and demonstrated it for the passenger mobility domain (Elzen et al., 2004). In this paper we elaborate the methodology and demonstrate it for the electricity domain.

The STSc methodology builds upon recent insights in the dynamics of innovation processes, more specifically on a transition theory known as the "Multi-level Perspective" (MLP). The MLP studies innovation as the result of the interaction between three 'levels', notably the macro level of the socio-technical landscape, the meso level of a socio-technical regime and the micro level of technological niches.

The STSc method explores possible developments on all these levels and how they may influence one another to give a 'richer' picture of possible pathways towards sustainability. The method is illustrated by a concrete example of such a transition path for the electricity system. The paper ends with an assessment of the usefulness of the method as an instrument in transition policies that target the development of a sustainable energy system.

Introduction

Developing a sustainable energy system is an enormous challenge. Despite many reports that suggest otherwise the main challenge does *not* seem to be of a technical nature: with proven technologies it is possible to design an energy system that produces only a fraction of the emissions (CO_2 as well as pollutants) of the current system (IPPC, 2001). Rather than a lack of good technical solutions the problem seems to be that there are too many potential (partial) solutions. Since each of these solutions has its own advocates it is very difficult for decision-makers and others to make an assessment of their potential and to decide which of these options to support and/or implement. An additional problem is that a transition to a sustainable energy system will require a combination of a variety of alternatives and it is very difficult if not impossible to oversee where such new combinations could lead to.

A major tool to deal with such uncertaincies is scenario-analysis. For decades, various energy companies, research organisations and international bodies (e.g. IEA/OECD) have developed energy scenarios to help assess which strategies would seem most promising (EPRI, 1999; IEA, 2006). From the transition perspective, however, these scenario's have a serious shortcoming: they have a strong technical bias, typically describing the (economic) diffusion of specific technologies. Thus they ignore one of the basic features of a long-term transition process which is that technical change and societal/behavioural change go hand-in-hand. In other terms, these scenario's typically only look at the energy supply side while they ignore that energy demand will change (quantitatively as well as qualitatively) in the same process. To remedy this omission requires the inclusion social science insights.

In this paper we will contribute to this challenge by describing a new method which pays due respect to the socio-technical nature of innovation processes, called the "Socio-Technical Scenario" (STSc) method. In earlier work we have described a crude version of the methodology and demonstrated it for the passenger mobility domain. (Elzen et al. 2004) In this paper, that results from an ongoing project, in which we collaborate with natural scientists, we are elaborating the methodology and will demonstrate it for the electricity domain.

Requirements for transition scenarios

If scenarios are to be used as a tool to induce transitions towards sustainability they should display the basic features of transitions. This implies that a transition scenario should feature the following characteristics:

1. Transition scenarios should show *socio-technical* development, i.e. it should describe the co-evolution of technology and its societal embedding. This is called a 'leapfrog' dynamic, i.e. a continuous leapfrogging of technical and societal change.

   This implies a scenario should pay attention to technical development as well as societal or behavioural aspects such as institutional change, different types of actors, their goals, strategies and resources, etc. It should show how radically new innovations, that misfit the regime initially, are developed further (in so-called technological niches) and how learning processes take place in which such innovations can eventually 'breakthrough' and may start a transformation of the regime characterised by technical, institutional as well as societal change.

2. *Continuous development*: Transitions are rarely the result of the 'simple' diffusion of a new technology but the technology changes continuously, combines with other technologies, splits into different lines of development, etc.

   This means that innovation is seen as a continuous process of change, not only of technologies but also of rules and institutions and the societal embedding. Historical studies show, for instance, that radically new innovations which, in retrospect, can be seen as the seeds of a transition are often tried out in a variety of successive application domains (via a process called niche-accumulation) until they find a domain where a major 'breakthrough' starts.

Because it should address qualitative change a transition scenario should tell a qualitative story rather than a linear diffusion story of technologies. It should present the story of possible future socio-technical developments as a good historian would tell it. Thus, a transition scenario could be read as a possible 'history of the future'.

The need for for a new "Socio-technical" scenario method

There are several scenario methods and projects for the long-term exploration of fundamental and systemic change processes (30-50 years). We have evaluated a range of scenario projects from different classes of methods in order to establish their appropriateness for exploring transitions. In a forthcoming report we assess these methods and projects in view of the specific transition requirements mentioned in the previous section. (Elzen and Hofman 2006) Below follows a brief summary of these findings.

Forecasting methods, especially those in combination with narratives, pay some attention to the co-evolution of technology and society at an aggregate level, and allow for the uptake of radical technologies as they are assumed to follow certain learning curves. However, there is limited attention for the processes that *underly* the co-evolution of technology and society, i.e. learning processes and interaction processes at the level of actors, the way they initiate and navigate changes in institutional settings, regulatory policies, infrastructure developments, and changing user preferences. Overall, these methods therefore tend to produce scenarios that have a mostly linear character based on extrapolations of the present.

Foresight methods pay attention to potential outcomes of processes of co-evolution of technology and society and the uptake of radical technology. The likelihood of these outcomes is assessed by looking at driving forces and the way these may unfold. This often takes the form of a focus on two dominant driving forces in combination with opposite directions in which they may develop, effectively leading to four different scenarios. While these scenarios are of a less linear nature than those produced through forecasting, limitations lie in their macro-orientation and lack of attention for the way learning processes and co-evolution take place through interactions at the micro and meso levels. Overall, these methods are useful in producing alternative futures that differ widely, but provide limited insight in the way these futures may unfold through interactions and learning processes at different levels and between a variety of actors.

Backcasting methods have a strong focus on the co-evolution of technology and society. They start from normative futures based on the premise of both technological and societal change. Changes in actor networks, shifts such as those from a product to a service economy (implying also cultural changes) are important cornerstones of the scenarios. Interactivity is also key to these methods, with stakeholders participating in the development of scenarios, such as to create some shared vision regarding the future.

More limited in these methods is attention for the way these transition paths may occur, also because of a lack of specification of how learning processes occur that may lead to uptake of radical practices

Technological roadmapping methods have a strong focus on technical aspects, without taking into account how actors, their strategies and interactions may influence the rate and direction of that technological change. The interaction with society tends to be limited to how a research agenda is given shape.

Breakthrough methods focus on individual projects, companies and technologies and much less on the way a broader process of socio-technical change is set into motion. This leads to a strong focus on the micro level, with a bias towards the innovators and consumers as core actors. Moreover, these methods are specifically designed to indicate actions for companies to be taken in the short-term and are less suited to explore long term processes of systems change.

An overall picture of the state of the art regarding scenario making indicates that there is increasing attention for the construction of future worlds through a process of foresighting and through backcasting from a desired future world towards the present. There is increasing attention for societal, cultural and institutional factors that influence the way our future may unfold, relative to the focus on 'hard' factors such as economic growth, prices, population growth in forecasting oriented projects. But only a limited number of projects are able to capture some of the complexity of the dynamics of technological change, with a focus on actor strategies and interactions, and processes of learning.

Our main conclusion from the analysis above is that none of scenario projects and methods satisfies the requirements for transition scenarios described above, although most score well on some aspects. But to encompass the entire complexity of system innovations, there is a need for a new tool which we call "socio-technical scenarios" (STSc).

To be able to account for the main characteristics of a transition the STSc-method will be rooted in the so-called 'multi-level perspective' (MLP) on transitions.

The dynamic of transitions – MLP

Three interacting levels

The so-called 'multi-level perspective' has been developed to analyse and explain transitions and system innovations. This perspective distinguishes three levels (Kemp, 1994; Schot, Hoogma and Elzen, 1994; Rip and Kemp, 1998, Kemp, Rip and Schot, 2001; Geels, 2005):

1. The meso level of 'socio-technical regimes' (S-T regimes) which denotes an existing socio-technical system that is embedded in society and links together a wide variety of societal actors (e.g. companies, public authorities, users/consumers). Regimes change continuously but the change, technical as well as societal or behavioural, is of an incremental nature, building further upon an existing socio-technical configuration (following 'path dependiencies').

   In the domain of electricity, for which scenarios are described in an appendix, the socio-technical regime is characterised by fossil-based supply chains and energy technologies, an important role for the electricity grid, rules for connection and transmission tariffs, and grid operators, and increasing competition and concentration across national borders as domestic electricity market become more open. Processes of liberalisation and internationalisation have reduced stability of national electricity regimes in the past decade and provide starting points for transition paths.

2. The micro-level of 'technological niches'. This denotes protected spaces in which radical innovations are developed. In their initial stage, these innovations cannot compete with existing technologies and need to be protected against regular market forces. Niches are important as a learning space on issues like technology, user-preferences and -practices, regulation, etc.

   In the electricity domain a large number of niches is and has been developed in recent years, such as a range of renewable energy sources and technologies, fuel cells and micro cogeneration, and clean fossil options. Some options are increasingly embraced by regime actors, such as biomass co-combusted in coal-fired power plants, others are supported by more diverse networks of actors such as in the case of off-shore wind farms where incumbent energy companies work with wind turbine producers and off-shore firms, while for fuel cells and photovoltaic power development firms based in other industries tend to be dominant.

3. The macro-level of 'socio-technical landscape'. This denotes the 'external environment' and consists of factors that not only affect the regime under analysis but a variety of other regimes as well.

   Relevant landscape factors in relation to the electricity domain include the development of oil prices, the process of European integration, the increasing pervasiveness of ICT technologies, and societal and political attention for environmental and climate concerns.

Figure 1 sketches a multi-level configuration and indicates how the levels may influence each other.

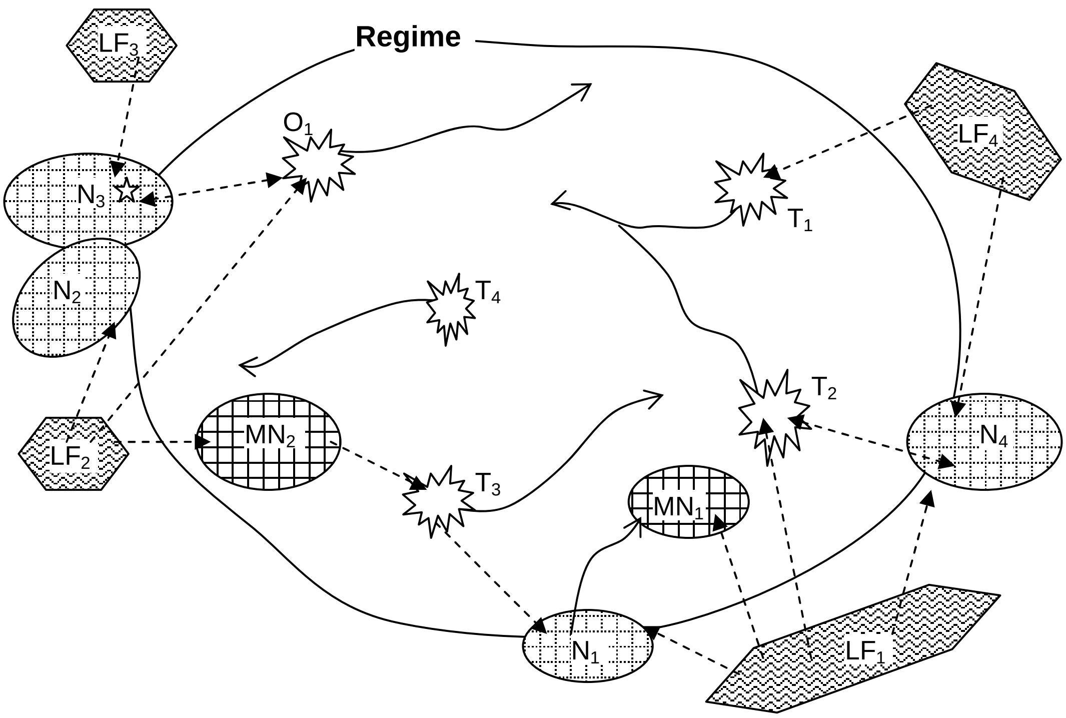

Figure 1: Sketch of the multi-level model

The niches are indicated by the small ovals N1 - N4. They typically have a partial overlap with the regime (e.g. by using shared technical elements or through actors that operate in the regime as well as in a niche). Some niches may have a partial overlap with each othter (e.g. N2 and N3). A niche may also transform into a market niche (MN1, MN2) meaning that it can survive without protection as a subsection of the regime.

Various landscape factors are indicated by the hexagons LF1 – LF4. Landschape factors can be 'all around' and may influence the regime, various niches or the links between niches and regimes. Niches and the regime may also influence each other as indicated by various dashed arrows.

Landscape influences and developments in niches may create tensions (arrow-shaped pentagons T1 – T3) or opportunities (O1) in the regime. Tensions can also emerge internally within the regime (T4).

From the tensions and opportunities new developments start as is indicated by the bended arrows. The bended shape indicates that the developments are not straightforward although there is a sense of direction due to path dependendies, at leas in the short term. Some developments may 'link up', e.g. the developments emerging out of T1 and T2 in the figure.

Radical innovations in niches cannot easily break through in an existing regime because the latter is very resilient. If a new radical innovation 'threatens' the regime (e.g. wind- or solar power), actors in the regime usually try to improve the performance of the dominant technology to counter the threat (e.g. by end-of pipe emission reductions). Furthermore, there is often a mismatch between the characteristics of the new innovation with existing user preferences and existing regulations. (Freeman and Perez, 1988).

Still, as various historical studies show, radical innovations can form the seeds for transitions. Their chance of breaking through can increase when the existing regime becomes less stable which may result from internal problems or negative externalities that cannot be solved adequately. Usually, such breakthroughs follow from mutual reinforcement of several technologies and they do not happen suddenly but result from successive small steps. In the MLP this is called 'niche-accumulation', i.e first application in small market A, then small market B, and only after various such steps, mass market C. (Cf. Geels, 2005)

The dynamic of transitions: pathways, patterns and mechanisms

Transitions take a long time, typically in the order of decades. Although they are very complex processes, the multi-level approach makes it possible to distinguish a limited number of characteristic patterns that a transition may follow.

First, we can distinguish an overall pattern, that describes a transition from start to finish as it were. This is called a transition pathway and in a forthcoming paper, Geels and Schot have distinguished four typical transition pathways. Which path develops depends upon two critical factors which are (1) the nature of the multi-level interactions and (2) the timing of the crucial interaction(s).

1. *Nature of interaction*: Do niche-innovations and landscape developments have reinforcing relationships with the regime or disruptive relationships through pressure or competition?
2. *Timing of interactions*: Different *timings* of multi-level interactions have different outcomes. Especially the timing of landscape pressure on regimes with regard to the state of niche-developments is important. If landscape pressure occurs at a time when niche-innovations are *not* yet fully developed, the transition path will be different than when they *are* fully developed.

Using combinations of these two criteria, Geels and Schot have developed four different transition pathways: transformation, reconfiguration, technological substitution, and de-alignment and re-alignment. In their analysis, they also pay attention to social groups and interactions, thus complementing a structuralist 'outside-in' approach with an 'inside out', agency-oriented perspective. Table 1 summarises the four transition routes and the roles of *main* actors therin (not *all* actors).

Transition pathways	Main actors	Type of interaction	Characterisation
1. Transformation	Regime actors and outside groups (social movements)	Regime outsiders voice criticism. Incumbent regime actors adjust goals, guiding principles, search heuristics.	Outside pressure, institutional power struggles, negotiations, adjustment
2. Technological substitution	Incumbent firms versus new firms	Newcomers develop novelties, which compete with technologies from regime actors.	Market competition
3. Reconfiguration	Regime actors and suppliers	Regime actors adopt component-innovations, developed by new suppliers. Competition between old and new suppliers.	Cumulative component changes and new combinations
4. De-alignment and re-alignment	New niche actors	Incumbents lose faith and legitimacy. Emergence of many new actors, who compete for resources, attention and legitimacy.	Erosion, collapse, co-existence of multiple novelties, prolonged uncertainty, competition restabilisation

Table 1: Taxonomy of transition pathways and the main actors (Geels and Schot, forthcoming)

To refine the analysis, these transition pathways can be broken down into various shorter term patterns of change. Specific combinations of these patterns then make up the various transition pathways.Given the characteristics of transition processes discussed earlier and the typology of transition pathways these patterns should at least cover the following :

- describe technical as well as societal/behavioural change;
- describe developments in the regime under different circumstances, viz:
  - independent from landscape development as well as under pressure from it;
  - independent from niche development as well as under pressure from it;
  - links between niche and regime developments;
- describe internal niche developments, with and without landscape pressure.

Some examples of such patterns are:

- Market diffusion of a new technology (a typical pattern that is often used as the primary dynamic other scenario methods);

- Hybridisation: a new combinatinon of two options that were separate before;
- New user preferences (e.g. emerging from landscape pressure or new regulation) that diffuse further;
- Niche accumulation (an innovation moving to various successive new application domains);
- Niche proliferation (spreading of an innovation to new domains).

We want to stress that these patterns are, compared to the overal transitions pathway, relatively short-term phenomena. Many consecutive patterns together make up a transition and by a combination of patterns of technical and societal change the overall dynamic of co-evolution emerges.

A 'mechanism' describes a short term phenomenon that triggers the onset of a new pattern. A mechanism zooms in to the actor level to describe how specific actors create something new, e.g. a technical novelty, new user behaviour, new policy, etc. A mechanism creates or enables a new link between entities that were not linked before. This new entity can subsequently become the starting point for a development that follows one of the patterns above. The result of a mechanism can be a novelty that can either be a technical innovation or a societal / behavioural innovation (or a combination of both).

A specific combination of mechanisms and patterns leads to a specific pathway and thus defines a transition in a specific case. We can then use these same mechanisms and patterns to constuct transition scenarios.

STSc methodology

Main characteristics of STSc

A transition scenario does not have to display all the complexity of historical transitions. What it needs to do is to display the basic features of transition processes to produce some scenarios with sufficient contrasts to serve as a foundation strategic or policy advice. On the basis of the discussion above we have identified the following main characteriscs STSc:

- A strong emphasis on the socio-technical nature of change processes (co-evolution);
- This results in a 'leapfrog' dynamic with sequences of changes, sometimes more on the technical, sometimes more on the societal and behavioural side.
- The analysis concerns developments within and between three different levels, viz. niche, regime and landscape;

  The regime is the central level at which transitions may take place. Regimes account for stability (showing path dependencies) but broad transformations may occur over long periods of time through pressures that may come from within the regime, from the landscape level and from novelties in niches that try to hook on to the regime (sometimes re-enforced by the landscape or internal regime pressures). A novelty may then start to grow at the expense of the regime and by 'eating it from the inside' (basically by making its users desert to the novelty) gradually transform it.
- Other scenario-methods have a 'macro-bias' (all of them?): they use a small number of 'driving forces' that define a number of contrasting scenario's. In an STSc there are no specific driving

forces and contrasts are created by different qualitative links within or between the three levels that trigger developments in new directions.

- Zooming in/zooming out: When a 'stable situation' is at hand (a dynamic equilibrium) we zoom out to the regime level and only look at 'broad patterns'. However, when crucial new links are emerging we zoom in to the individual actor level. Here we look at the concrete actions, strategies, expectations, links, etc, i.e. the mechanisms that may start new patterns to develop. When repetitive general patterns emerge we zoom out again and look at these patterns rather than at individual actors.

STSc Core methodology: building boxes and episodes

Based on the discussion of the multi-level perspective above we can define what we call the 'STSc Core methodology', i.e. that part of the methodology that applies to any STSc. This core does not yet suffice to actually make an STSc in a specific case because that also depends upon the objectives of making a scenario in a specific case as will be discussed further below.

Historical transitions have followed a wide variety of courses. To be able to develop scenarios, however, this variety needs to be reduced although we should take care not to end up with a model in which outcomes are completely determined by 'driving forces' and 'factors'. What we are looking for is the middle course between 'chance' and 'necessity', in line with a long-standing debate within evolutionary theories.

A first reduction of complexity is to to limit the infinite range of possible scenarios to the four 'idealtype' transition distinguished in the table ## above. Which of these pathways are actually used will depend upon the specific scenario objectives discussed later.

Within these pathways, however, developments can follow an infinite array of courses. In this STS method this variety is used by only using the patterns and mechanisms that are discussed in the section on the dyanamic of transitions above. The four transition pathways together with the patterns and mechanisms define the conceptual building box of an STSc.

All of the above patterns and mechanisms in principle can occur at any time in a transition. Yet, to highlight the transformational aspect of a transition it is helpful to focus on different aspects in different stages of a transition. Loosely based on a model by Rotmans et al. (2001) we distinguish four stages in a transition that are translated into four consecutive episodes that make up a transition pathway in an STSc. These episodes are:

1. *Disconnection episode*: in the first part of the scenario the emphasis is on how regime and landscape pressure create room for the development of various niches, what type of learning takes place, how niches try to address the problems in regime and landscape, how links between niches develop (hybridisations), etc. Concurrently, the regime also evolves (possibly, partly under landscape pressure) but there is relatively little interaction between niches and the regime (hence the phrase disconnection).

2. *Linking episode:* in the second part of the scenario some niches link up or affect what happens in the regime which starts having a visible impact, e.g. by the development of a niche market or hybridisations between niche and regime configurations or by the regime seeking to improve to counter possible niche-threats (sailing ship effect). The existing system is still dominant but there

is a 'serious threat' that the novelties resulting from the linkages have better longer term prospects than the existing regime configuration;

3. *Transformational episode:* in the third part the novelties (either evolved niches or new regime configurations) gradually take the upper hand. The reasons may include better performance, better potential to tackle problems, new regulation, etc. This happens not only through diffusion of the novelties but in a continous process of new links and socio-technical change;
4. *Evolution episode*: In the last stage of the scenario, the novelty has taken the upper hand and defines a new regime. Subsequently, a 'conventional' process of incremental change follows to improve performance and/or tackle newly emerged problems. At the same time, new niches may emerge and evolve, initially separate from the regime. The dynamic in the fourth episode resembles that of the first but now after a transition, i.e. with a new dominant regime.

Following these episodes, an STSc can be seen to consist of four chapters in which the dynamisms described follow one another. They form the main structure in the design of a scenario and define the overall architecture, as it were.

Steps in making an STSc

On the basis of the discussion above we have defined 8 steps in the STSc methodology that should be followed in making a scenario and use it as a tool for strategic or policy advice. The steps should not be taken to rigidly in a consecutive fashion and there can be some jumping back and forth, especially in the process of developing the scenario architecture(s) (up to step 5). Where to start may partly depend upon how well the analysts is acquainted with the domain in question. For instance, if the analyst is not well acquainted it might be advisable to start with step 2, mapping the current dynamics.

The steps are defined as follows:

Step 1: Specification of scenario objectives

Step 2: Analysis of recent and ongoing dynamic

Step 3: Inventory of potential linkages

Step 4: Design choices

Step 5: Develop scenario architectures

Step 6: Elaborate all scenarios

Step 7: Reflection and evaluation

Step 8: Developing recommendations

Each of these steps will be briefly elaborated in the following sub-sections.

Step 1: Specification of scenario objectives

Scenarios can be targetted at different types of users and serve different functions. To explore future transitions we distinguish four broad categories of scenario objectives for the STSc, notably:

1. Stretch mental maps and increase awareness and acceptance of 'radical' alternatives;
2. Explore potential of portfolio of promises by sketching different transition paths;
3. Inform policy-making and business strategy;

4. Serve as co-ordination and alignment tool.

These functions partly determine the requirement for a specific scenario in a concrete case. The objective to inform policy and strategy, for instance, would require lengthier scenarios with more detail than is required to stretch menatal maps. Choices will have to be made on several issues that will result from the analysis in step 2, including:

- Which regime to look at (regime of focus);
- Which niches to look at;
- Relevant landscape factors;
- Possible other relevant regimes.

Step 2: Analysis of the current dynamic

The next step is to map the current dynamic and state of affairs in the domain of interest using the MLP. This implies having to analyse all three levels, i.e:

- Regime dynamic, problems, strategies and trends
- Relevant landscape factors (including 'enabling technologies')
- Relevant niches: dynamic, opportunities and barriers for transition

Which factors to take along was determined in the previous step. A protocol has been developed to map the dynamic within and between these three levels that has been described elsewhere.[1]

Step 3: Inventory of potential linkages

We will discuss this step in considerable detail since it concerns a crucial feature that distinguishes the STSc method from other scenario methods. One of the shortcomings of the latter in exploring transitions is that these methods often leave the current basic features of technologies untouched as well as how they are used while historical studies of transitions show that new combinations and/or new user behaviour often form the 'seeds'[2] of a transtion. STSc does allow such qualitative changes and to exploit this the analyst needs to make an inventory of possible new links. Such a linkage can by any type of 'qualitative' new relationship between different elements, e.g. a landscape pressure linking up to a niche and/or a regime technology, to a new type of user behaviour. Some typical examples are:

- hybridisations: the merger of two options to create something new (e.g. hybridisation of gas turbine and steam turbine leading to combined cycle gas turbines;
- changing user patterns: a combination of institutional and technological change may induce (initially small) groups of users to change their behaviour and these groups may grow under specific circumstances (e.g. the emergence of green electricity in the Netherlands as a separate customer product due to an increasing market orientation within the sector and public concern regarding climate change)

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[1] Rob Raven, *Protocol for regime analysis*, Internal report "Energy transition project", Eindhoven, 2006.

[2] I.e. the novel (S-T) combinations that could start a small initial change of the 'course of development' of a regime but, when consistently followed through, in the long run could lead to a transition (possibly by (re-) combining with other 'seeds')).

- links between technical development and political developments: for instance an electric vehicle with zero emissions (a technical element at the regime level) can get linked to strong determination to cut city pollution (a political element at the regime level).
- links between various regimes that enable certain niche developments. Multiple regime developments can create momentum for niches such as in the historical example of the gas turbine (military aircraft industry, aircraft industry, and power generation sector play important roles in the development of the niche, and in the current example of the fuel cell, which is both driven by opportunities for use in the transport and power sector.

The potential of such new links to occur is the main distinctive feature of STSc compared to other scenario methods. These linkage possibilities we call 'transition elements' which are defined as elements at each of the three levels (regime, niche, landscape) that could link up to create novelties as a potential prelude to a transition. For instance an electric vehicle with zero emissions (a technical element at the regime level) can get linked to strong determination to cut city pollution (a political element at the landscape level). The result could be a new type of 'city electric vehicle' that starts having noticeable effects at the regime level.

Transitions imply the breakthrough and take-up of new technologies along with a transformation of behaviour of various actors in relation to these. A starting point to identify them could be to identify a number (for example 5 to 10) novelties (technologies, concepts, new forms of societal embedding) that could be part of linkages between niche, regime and/or landscape level) with good 'sustainability performance'. Also potential 'enabling technologies' (e.g. generic technologies, like ICT, that could be taken up in a variety of regimes) could have a substantial impact on the dynamic of either one or both of our two domains.

Transition elements not only concern technologies. Transition theory distinguishes several articulation processes that play a role in the breakthrough of niches. Each of these processes defines a specific type of dimension that could play a role in a transition implying the following types of dimensions should be addressed:

- technical dimensions
- policy dimensions
- cultural and psychological dimensions
- market dimensions
- production dimensions
- infrastructure and maintenance dimensions
- societal and environmental (problems) dimensions
- financial dimensions

The linkage opportunities identified in this step can be used when actually making the scenario. Whether they will indeed be used will be decided during the actual construction of the scenario when, based upon transition theory, it can be made plausible that such a new link will occur.

Step 4: Design choices

This step can be seen as a further elaboration of step 1 but with the additional information on the regime collected in step 2. In the fourth step further design choices will have to be made, e.g. on the number of scenarios to make, the time-frame to be used (e.g. 30-50 years) and main distinctive features between the scenarios. This step sets the stage for the steps to come in which these general characterisations are filled in in further detail.

Traditional scenario methods often work with a two dimensional matrix, e.g. with one dimension related to economic growth and the other to the urgency of environmental problems. This matrix defines four scenarios. From the perspective of a transition, however, the contrasts between scenarios thus defined is not very large in the sense that all scenarios typically are technology diffusion scenarios, not leading to any substantial change on social dimensions. As the main feature of STSc is that it does provide for a sociotechnical dynamic the method should illustrate potential contrasts along social as well as technical dimensions.

Above, we distinguished for functions for STSc transition scenarios. In a forthcoming report (Elzen and Hofman 2007) we have elaborated various requirements for each of these funcitons which are briefly summarised below:

1. *Stretch mental maps*: Two rather brief scenario's (say, 5 pp. each) could suffice to make acceptable for the audience that radical changes are quite plausible as the result of small steps over a longer period of time.
2. *Explore portfolio of promises*: This would require lengthier scenarios (say, 15-20 pp.) to illustrate how several of those promises could develop further, link up to each other and/or the regime to form 'the seeds of a transition'. The number of scenarios would have to depend upon how many of those promises need to be explored and what possibilities there are for various cross-linkages. Two scenarios is a minimum to create sufficient contrast but in other cases several more may be needed.
3. *Inform policy-making*: The general requirements are comparable to the previous point but in the scenario a variety of policies should be highlighted and explored. Thus an assessment can be made of possible effects of various policies under different circumstances in terms of the multi-level dynamic. To explore the 'robustness' of various policies additional scenarios could be made with diverging relevant landscape factors (e.g. very different petroleum prices or a different sense of urgency on the need of curbing CO_2 emissions).
4. *Co-ordination and alignment*: we have only started to elaborate this option. On the basis of an earlier experience it does not seem very fruitful to develop a 'complete scenario' in an interactive session as a lack of focus makes such an exercise very messy. What seems more useful is that the organisers of such a session develop one or two so-called 'framework scenarios' and that the interactive session focuses on crucial 'bending points' (the point where a niche links to the regime and starts transforming it) in these scenarios. The discussion in the interactive session could focus on the factors that could either make such a bending likely or that might create barriers for it.

These general requirements should be further specified. Concretely, choices have to be made in relation with the following:

1. Timeframe

2. Number of scenarios
3. Which transition pathways to include (the four distinguished by Geels/Schot)?
4. Which regime(s); include multi-regime interactions
5. The role of the S-T Landscape
6. Which niches to incorporate; linkages to use
7. Miscellaneous items: there are a number of concrete things that need to be addressed, mostly under one of the other points above, for example:
   - Level of detail for each scenario;
   - Variables to use
   - Specific points of focus (e.g. specific technologies (to be more precise: socio-technical configurations), specific policies, etc.);
   - Patterns and mechanisms to use

Step 5: Develop scenario architecture

For each scenario, first a 'scenario logic' should be described which is a very brief general story (app. ½ page) of how the scenario will develop. The scenario logic uses some of the potential linkages identified in step 3 to describe a dynamic that is formulated following the main characteristics that Geels and Schot (2006) identified for each transition pathway (i.e. the type of niche-regime interaction and how this is affected by (the timing of) landscape pressure).

Having followed the earlier steps results in an inventory of potential linkages (the result of step 3), some variables to use and a number of selected transition pathways (with scenario logics). The linkages and variables should subsequently be distributed across the different scenarios. The main criterion for this distribution is that the linkages and variables fit the logic of the scenario for which they will be used. The goal shoul *not* be to aim at an 'even distribution' but to develop a number of 'plausible' scenarios, i.e. scenarios that are consistent with the multi-level dynamics.

This results in the definition of a number of different scenarios in which each scenario is defined by a scenario logic and a number of linkages that should be used. The linkages will allow filling in the scenario logic with much more datail to develop a complete storyline (called the 'scenario skeletton') for each scenario. The time-frame of the skeletton should follow the four episodes distinguished earlier for easy comparison of the scenarios.

Step 6: Elaborate all scenarios

The STSc-skeleton provides the last step before the actual writing of the scenario. What remains to be done is to put flesh to the bones of the skeleton by adding a level of detail that makes the various new links plausible in view of the multi-level model and that thus helps to pinpoint various concrete factors crucial in inducing and supporting a transition.

If we would have the ambition to write a six page history of a transition (for instance the energy supply regime in the period 1900-1950) from a multi-level perspective, it would have to be rather superficial, i.e. we could only use a 'broad brush' to sketch the regime developments and could only treat a couple of niches with hardly any detail. Other niches we would have to let emerge and affect the regime in just a few sentences.

In connection with an STSc we face exactly the same problem, implying we very much have to limit ourselves. This begs the question to what the ‘minimal requirements’ are for an STSc to be ‘convincing’. Some suggestions:

- Address all three levels to some extent. Use the regime-level as the thread through the story. Discuss a limited number of exemplary niches. Indicate how a limited number of landscape developments affected expectations and subsequent developments in the regime and the niches discussed.
- In the niches, pay attention to articulation processes. When a niche ‘breaks through’, make plausible all relevant ‘articulation barriers’ have been overcome. A niche is not only a technology but also a domain of use that should be described. Within a niche, an ‘ordering principle’ could either be specifc technologies or a specific domain of use.
- Watch out for (too) linear stories. Also introduce some cross-links, bifurcations, hybridisations, etc.
- Make the role of various actors clear (producers, users, government). Describe how they are guided by their expectations and how their expectations are influenced by developments and experiences at the three levels.
- Treat technical and social/behavioural issues ‘symmetrically’; pay serious attention to co-evolution. Describe, e.g., how new technology leads to new experiences and then to new behaviour.
- Patterns and mechanisms; the theory provides a wide range; use them selectively and name them explicitly.

Step 7: Evaluation and recommendations

In the final step the scenarios will have to be evaluated against the background of the opbjectives from the first step. They can be used, for instance, to develop policy recommendations as will be illustrated at the end of this paper.

Scenarios for the electricity regime

Above, we showed that that STSc method allows the construction of a wide variety of transitions scenarios. Which type is chosen depends on the more specific reason a scenario is made in a specific case. In this paper, our main purpose is to briefly describe the method and to give the reader ‘some feel’ for the type of scenarios that could result from this. For that reason, the scenarios below illustrate how different multi-level dynamics may lead to two diverging transition paths. The different steps within the methodology are summarised below, followed by brief scenarios.

Step one: scenario objectives

Regarding the scenario objectives, *step 1 in the methodology*, a main objective here is to illustrate the type of multi-level and multi-regime patterns and mechanisms that may characterise fundamental long-term tranformations of existing sociotechnical systems and shifts to new sociotechnical systems. This is relevant for a range of potential users and should particularly function as a means to stretch mental maps, enabling actors to envision new technological, organisational, and institutional configurations of the sociotechnical system for electricity production and use, and to envision possible routes towards those configurations. It could help to overcome prejudices about what is or is not realistic.

Step two: analysis of ongoing dynamic in the electricity system

The scenarios start from the current dynamics within the electricity system. The first episode of the scenarios (disconnection) concerns the ongoing transformation of the electricity system and the main characteristics of the initial dynamics are briefly described in the next paragraph.

Rules and routines in the regime and the way they are evolving strongly impact the scope, variety, direction and speed of potential transition paths. Especially the control of electricity flows and the design of electricity networks are in transformation with one trend towards stronger involvement of network operators regarding high voltage transmission (Tennet in the Netherlands) and increasing European coordination, and one trend towards more diverse electricity flows with a diversity of private actors and organisations organising electricity systems at local scales. Private actors are reluctant to invest in new power plants, especially those of significant scale, as the (long-term) conditions under which these plants may be economic are unclear because of volatile public frameworks as well as volatile energy prices. Finally there is uncertainty regarding the type of technology that is future-proof as regulatory frameworks regarding carbon emissions beyond Kyoto are unknown and because it is difficult to assess which fuels are the best bet in the medium term.

Summarising, the electricity regime is regarded to be in flux and is characterized by traditional actors trying to cope in diverse ways with this flux, while new entrants try to exploit ongoing processes of change within the system.

Steps three to five: Design choices and architecture of the scenarios

For the sake of brevity, we have taken these steps together in this paper. Two contrasting scenarios are constructed, in order to show how different multi-level dynamics can lead to diverging transition paths. In step 1 above, two contrasting types of transition pathways were chosen that need to be filled in further taking the main characteristics from step 2 as a starting point. The first scenario follows the pathway of reconfiguration, where the electricity regime becomes increasingly international of character, facilitated by developments in transmission networks and coordination among countries. The second scenario follows the pathway of dealignment and realignment, where the large-scale and central orientation of regime actors becomes increasingly discredited and local systems developed by new actor networks gain increasing legitimacy. Table 2 summarises various the design choices we have made to create these contrasts (at the landscape, regime and niche level) and some key characteristics of the scenarios.

Table 2: Design choices and architecture of the two scenarios and transition paths.

Scenario title	**Reconfiguration pathway:** **Towards European electricity systems**	**Dealignment and realignment pathway:** **Towards distributed generation**
Main characteristics	Regime actors develop more international orientation facilitated by	New networks of actors develop more local based systems facilitated by increasing

	development of an international electricity highway. EU policy and intergration plays a leading role in the process. Renewables adapt to the system.	difficulty of regime actors to cope with landscape pressures. Competition between large-scale supply orientation of regime actors and the local demand orientation of new actor networks.
Dominant networks	Networks with traditional electricity producers, distributors and central government actors; oil and chemical sector become part of electricity regime	Networks of energy distributors, engineering & ICT firms, construction companies, housing associations and municipalities
Policy	Strengthening of international grid, EU emergy policies, European security of supply	Local energy policy, stimulation of alternative infrastructures, integration of energy in built environment
Landscape factors		
EU integration	Strong influence as European energy policy focuses on energy security and climate change	Some influence through institutional frameworks but main development in local energy policy
ICT penetration	Mediocre influence in fine-tuning supply and demand	Strong influence as ICT enables distance control of plants and local networks
Fuel prices	Important influence to support feed-in of bio-fuels and efficiency increases	Important influence to support shift towards renewables
Security of supply	Strong influence to develop self-supporting European electricity system	Strong influence to develop local systems with high resilience based on diverse energy technologies
Regime factors		
Infrastructure	Regime actors press for grid reinforcement to enable investments in large scale power plants	Crumbling off of dominance of centralised network as range of actors develop more local systems
Multi-regime interaction	Collaboration between energy companies, oil and gas sector to enable CCS	Actors from other regimes (ICT, gas, transport, housing) support niche development of local systems
Niche development	Hybridisation of niches with regime; niches adapt to dominant design of central station electricity	First niches because of differentiation in regime; niches slowly built new power system design of distributed generation
Main niches	Fossil generation with carbon capture and storage (CCS); Offshore wind power farms;Coal/Biomass gasification; based on international niche proliferation;	Micro cogeneration with small scale electricity generation technologies; Local power generation because of overburdened grid; ICT demand for reliable power; New housing districts with low energy impacts.

In the following sections, the 'skeletton' version of the scenarios from the table is elaborated into brief stories that shows the inteplay between de various levels.

Scenario 1: Reconfiguration towards European electricity systems

Note: The scenarios are written in the past tense, as a history of the future as it were. This is done to make the user focus on the plausibility of the story as it is. Using the future tense might easily trigger a reaction that something else could also happen (which is always the case) and divert attention away from the scenario character.

Overview

In this scenario political decision-making and more hierarchical forms of steering played a core role, with the European Union as a central actor both for the development of an European electricity grid and the achievement of Kyoto targets and beyond. This ongoing process was accelerated due to recognition that stronger international control and capacity of transborder flows could increase efficiency of electricity systems at an European scale and increase reliability of national power systems. Increasing collaboration and fine-tuning between tranmission system operators was the consequence, while also long term planning of power plant investments shifted to the international level.

Linking episode (2005-2015)

Increasing international trade in electricity and growing dependence of the reliability of national systems on crossborder capacity stimulated expansion of transmission capacity at borders across Europe. One factor was increasing pressure from the EU on countries to expand transmission capacity as to guarantee reliability of electricity systems and to enable free trade of electricity. The role of the EU in the electricity regime became steadily stronger as conflicts increased between countries regarding unfair competition and the lack of crossborder transport capacity. The EU therefore intensified its role in the harmonisation of the processes of liberalisation in the national electricity sectors, and the role of international bodies in the organisation of crossborder trade strengthened relative to the national grid managers. Energy companies were only prepared to invest in new power plants on the condition that the capacity for international flows of electricity was expanded. The lack of new investments in power plants of significant capacity led to the initation of public-private partnerships where national governments in collaboration with energy and oil companies made some large-scale investments in power plants (multiple resources, with carbon capture and storage, CCS) in order to increase security of supply and reduce carbon emissions from the system. As some of their investments came underway this is also reinforced the need for crossborder tranmission capacity. Especially the development of thermal power plants with CCS that were located near fields where carbon could be injected triggered further demand for stronger electricity grids. All in all this led to an increase in capacity for crossborder electricity transport and agreements regarding international reserve capacity.

Transformational episode (2015-30)

Landscape pressures peaked. On the one hand, security of supply was at risk as a lack of reserve capacity in certain regions led to large power failures and could be prevented by sufficient crossborder capacity while. On the other hand, the political and societal need to deal with the climate problem became inevitable through combinations of prolonged extreme weather and failure to reduce significant carbon reduction which mobilised international action.Until then renewable options remained confined to rather specific niches and had difficulty breaking through due to the stability of the regime and its specific technological demands. The amount of R&D in renewable energy at the European level also increased, and some large-scale projects were initiated.

While regime actors perceived that they were able to assimilate landscape pressure through incremental innovations, other actor groups increasingly felt that the existing system was unable to provide solutions for the challenges at hand. It was increasingly recognised that the initial Kyoto targets were well below what was needed to make any significant impact and more amibitious goals were set for 2020 and beyond. This coincided with an increasing need for replacement of obsolete fossil-based power plants that reached a peak after 2015. The combination of these two factors with a strong European grip on energy policy triggered a stronger technology-push of large-scale options, also facilitated by the process of EU integration, involving thermal power with CCS, gasification plants, nuclear energy and nuclear fusion.

In the portfolio, however, large scale development of renewables also started to play a more significant role: off-shore wind farms, biomass, and large-scale PV. The strengthening of the international grid and increasing international coordination of electricity flows also enabled further integration of off-shore wind farms within the system. Domestic offshore power grids start to expand (UK, Germany, Denmark, Netherlands), and master plans were developed and implemented to integrate these grids and to reduce overall intermittency of offshore wind farms. The uptake of a number of offshore windfarms within electricity systems increased the demand for international grids that could balance the volatility of large-scale wind power as for example hydropower from Norway and southern Germany served as back-up for Dutch and German wind power.

Evolution episode (2030-2050)

The process of European unification continued and political power increasingly shifted to the European level. Authority over high voltage grids had shifted from the national to the European level and the reliability of electricity supply was guaranteed through European law, rules and agreements. Infrastructure became geared for large scale generation and long distance transport and power plants became more and more located close to potential carbon storage fields. The regulatory system disfavoured local generation, as distributed generation was not generally viewed and accepted as a potential route to a carbon free electricity system. The electricity infrastructure development facilitated large scale integration of off-shore wind, while an infrastructure and legal framework for carbon storage was developed.

Expectations regarding large-scale solar power increased as further strengthening of the grid, long distance transport at higher voltage, and improvement of cable and conduction technologies, led to reduction of transport losses and made transport at longer distances possible. The EU intensified its collaboration with North-African countries on solar hydrogen systems that were developed in southern regions (Europe and Africa) as they served local hydrogen need and produced power for the international grid. In 2050, then, electricity demand in the Netherlands was met half by national power production with several highly efficient combined cycles based on inputs of gas, biomass and coal (with CO_2 removal) and offshore wind-hydrogen systems, leading to a halving of CO_2 emissions compared to the 1990 level. The other half was met by import of electricity based on combined cycles, offshore wind farms, solar hydrogen systems and hydropower.

Scenario 2: Dealignment and realignment towards distributed generation

Overview

Gradually, the legitimacy of the existing regime corroded as it was not expected to be able to deal with the climate problem. Market based support for large scale options continued but public funding focused more and more on new networks of actors that were developing regionally oriented projects where a combination of demand-orientation, smart mixes of various energy technologies, and regional infrastructure and control development took place. In this scenario broader public and societal actors played a more important role in devising bottom-up strategies for emission reduction and sustainable development, in interaction with instruments for climate change on the local and regional level and oriented towards users of energy and electricity. Local climate policy gained in importance within national and international climate policy making.

Linking episode (2005-2015)

Changing user preferences facilitated by liberalisation induced increasing divergence in strategies of mainly internationally operating electricity producers and more nationally focussed energy distribution companies. Producers supplied cheap base load electricity by full utilisation of their large-scale power plants based on coal, oil, gas or nuclear energy. Distributors were more focussed on customers with smaller electricity demand, such as households and small firms. They were attracting customers mainly by highlighting the specificity of their product and service. Distributors aimed to further expand market niches such as industrial combined heat and power production, in collaboration with industrial actors, and they further explored technological niches such as micropower in coalition with gas utilities and electric equipment producers.

Gas utilities were involved to expand the market of gas relative to central produced electricity. Several industries were involved because they needed electricity in combination with high quality heat that could be provided by microturbines. In the Netherlands powerful gas actors and electricity distributors initially played an important role through the development of micro-cogeneration. Initial projects on micro-generation led to further adjustments with projects involving a range of modular technologies as actors learned more and explored new combinations between more traditional energy technologies and more radical technologies involving fuel cells, storage technologies, and virtual control technologies. The promise of alternative energy technologies and its perfect match to the digital economy also got an increasingly stronger voice, even in regime circles (Yeager, 2004). ICT companies started to develop their own electricity systems as power interruptions were perceived as a major source of economic loss and customer dissatisfaction.

Leading edge companies followed examples in the USA and installed fuel cell stacks to secure their electricity supply. Several users needed more reliable power delivery for on-line financial transactions, exchanges and ICT operations. These companies installed local power back up that could handle short black outs. Also electricity contracts were settled between ICT, financial companies and energy companies that combined high reliability with high liability, and energy companies installed reliable local capacity with fuel cells for these companies. Agricultural companies also increasingly exploited ways to develop energy production as a way of diversifying their dependence on the volatile agricultural market. This took the form of exploiting side-products such as manure and waste products for electrity generation systems and expanding wind and solar power for local systems. Combinations and spin-offs of energy consultancies, engineering firms and distributors created energy service companies that organised electricity flows and contracts between co-producers, users within and between local systems and increased reliability of local systems by co-management of small scale power sources based on (bio)gas turbines, (bio)diesel engines, hybrid fuel cells-gas turbines. Some trials were designed in which fuel-cell cars were utilised as power sources to fill gaps produced by the intermittency of renewable based power systems.

Transformational episode (2015-2030)

Rules were increasingly adapted to work towards favouring regional and local systems. Investments in large-scale transmission remained difficult due to political discussion and expectations that local systems could meet rising demand. The success of local systems led to a range of small-scale applications being offered by energy service providers and engineering firms. Government schemes supported investement in carbon-lean systems through tax incentives. Different actors worked together in projects where energy provision was organised at the regional level, such as housing organisations, construction companies, project developers, municipalities, NGO's, ICT companies and agricultural businesses. Energy provision was less viewed separately but more as integrated in the development of housing areas, commercial areas, rural areas and industrial areas. Integrating various energy technologies into the built environment in combination with energy saving was more and more seen as the most promising route as it advanced by new owners of electricity systems such as housing organisations and ICT companies. Also agricultural businesses increasingly exploited side-products for energy provision and became owners of electricity systems.

New energy service companies emerged that dealt with the organisation of electricity flows within and between systems also based on contracts that discerned betweeen different qualities of electricity and enabled demand management from a distance through the application of smart metering systems. Actors from different regimes worked together to tailor energy technologies and systems to specific demand. Closed loop thinking became more and more dominant for industries and agriculture, energy-neutral houses were becoming the standard. Thus multiple component innovations started to work together, and this involved both new organisational concepts and systems of a variety of energy technologies, and slowly a new regime started to grow out of the old regime. Strong regulatory frameworks and incentives for carbon regulation emerged at the local level, carbon quota were also related to specific areas (with differentiation in types of zones), and municipalities played an important role in regulatory control and promotion of ways to reduce carbon emissions.

Evolution episode (2030-2050)

As the process towards distributed generation continued, around 2030 gas was still exploited as a resource for the production of hydrogen but its share in power generation was falling. Alternative options for the production of hydrogen steadily increased their share, such as hydrogen from biomass sources, wind energy and solar energy. Investments in power generation virtually all took place in flexible power systems that offered power close to the customers and were based on sources varying from wind and sun, to biomass and hydrogen. The systems were designed for specific local or regional demand for electricity, with connections to specific industrial users, commercial users and neighbourhoods. Also micropower systems continued to take a significant share of the power market. Investment in central capacity was absent in this period, although some larger power plants were built related to specific electricity and heat demand of industrial users.

In 2050, around 25% of electricity generation capacity was handled by relatively autonomous distributed generation systems. This emerged through the connection of previously independent small scale power generating technologies in local systems, facilitated by on-line monitoring and power management. Newly built neighbourhoods became self supportive for power generation while existing neighbourhoods increased their share of locally produced power. This was stimulated by new legislation that prohibited the construction of housing areas that drew external power. Standards were developed to increase the share of locally produced power in existing houses. Apart from wind and photovoltaic power, also locally produced biomass was becoming part of a local cycle of power and hydrogen production. Another 50 % of electricity generation was provided by decentral systems with a connection to the central grid. Around 25% was provided by central power plants that were not connected to specific users. Overall this resulted in a halving of CO_2 emissions compared to the 1990 level.

Reflection and policy recommendations

The two scenarios can be used as an aid to assess current strategies and policies within electricity circles, and to develop strategic recommendations. The two scenarios point out that ongoing dynamics in the current electricity system can offer starting points for diverging transition paths, which are both plausible but which may lead to very different outcomes in the long term. In our view this could provide clues for the development of policies, which are robust in the sense that they hold strength and relevance in both scenarios. This implies that policies need to be flexible in the sense that they are able to exploit changing conditions within and outside electricity systems. Based on the two scenarios we draw two main policy recommendations to support a transition to a sustainable electricity system.

Stimulate diversity of developments

In current processes of the formulation of policies and R&D agendas there is often a relative narrow range of actors involved. For example in the visioning process towards a transition of the electricity system in the Netherlands, there is a bias to a business approach to the energy transition, with strong representation of multinationals and energy companies, but under-representation of actors such as construction firms, housing companies, and consumer groups as reported in the initial visions and in the stakeholder consultation (Hofman, 2005). The strong focus on incumbent companies (regime actors) should be assessed critically as many have pointed out how difficult it is for incumbents to deliver more radical innovations (Henderson and Clark, 1990; Utterback, 1994; Christensen, 1997). Especially new start-ups, small firms, and outsiders are found to play a pivotal role in studies of radical innovation and systems change (Van de Poel, 2000; Geels, 2005). Incumbents are sometimes able to provide new products and markets, but evidence shows that it is often small, creative, new entities and networks developing new practices that provide the seeds for new sociotechnical systems.

The leading role of regime actors leads to a focus on large-scale renewable energy development, especially large-scale wind energy and the development of biomass applications within existing configuraitons. While the first scenario shows the promise of this path, a sole focus on large-scale integration has the risk of locking out other promising routes. This is unwise because there is much uncertainty whether large-scale integration will succeed. Factors that contribute to uncertainty are the shaky path of European convergence, problems of spatial integration and societal opposition, and the difficulty to integrate the various technologies into a reliable system. It is therefore sensible to encourage the formation of new networks and the inclusion of niche actors (such as ICT companies, agriculatural firms) that are more likely to invest in other promising routes, such as distributed generation. It would be a fail-safe strategy to invest more effort in exploring other routes, rather than betting on one horse. The scenarios show that most of the promising niches do not easily adapt to the central station electricity model and have other kinds of systems and infrastructure requirements. Hence, there is a need to build up experience with alternative infrastructures, such as those for biomass, hydrogen, and local microgrids. Real-life experiments are a good way to do this, also enabling further refinement of future visions on the basis of concrete learning experiences.

Overall, the general approach should be to stimulate diversity of developments in terms of infrastructure and actor networks and reduce the dominance of incumbents in R&D and policy.

Improve coordination between individual technologies and integration within systems

Much of the dynamic in the scenarios comes from new linkages that are created between different technologies. For example, the development towards an international electricity highway enables further development of off-shore wind-farms but also requires coordination between actors such as national governments and system operators. Similarly, the development of smaller scale energy technology depends upon integration of a variety of energy technologies within urban areas. Policy, however, tends to focus too much on individual technologies, and not on the type of coordination that is necessary to enable the technology to develop, and the type of combinations of technologies that play a role. These type of policies are too limited, because individual technologies may be unable to break out, because of specific constraints (such as wind, photovoltaic power and its intermittent character).

Overall therefore, there is a need for more focus on how the creation of new linkages between technologies and integration of sets of technologies within systems can be facilated by adapting rules and increasing coordination.

Conclusion

The primary aim of this chapter is to show the promise of sociotechnical scenarios as a reflexive tool for transition policy. Sociotechnical scenarios are not predictions of the future but can help to design more robust transition oriented policies. They can give insight in the various complex processes at work in systems change, in driving forces and promising combinations of technological, societal and institutional change. The development (e.g. in an interactive setting with various stakeholders from the domain of interest) and use of sociotechnical scenarios (e.g. expert-based scenarios) by policy makers can make them more reflexive for strategic considerations related to promising technologies and their potential to link up with other technologies and changing user preferences. The two examples of transition paths illustrate that the methodology can indeed lead to scenarios in which a transition emerges, not as a *deus ex machina* but as the result of plausible new linkages under specific conditions. Specific innovations and changing user preferences have been identified that can form the seeds for a transition and thus are good options for experimentation in the near term.

Very importantly, these options should not be treated separately but possibilities to create links between them should be explored. Processes of hybridisation and linkages between technologies and specific user preferences are core aspects of transition policy, not just single technologies. Thus the two scenarios illustrate that the construction of sociotechnical scenarios can not only help to create visions of a sustainable future, it can also help to identify potential transition paths that can lead to such futures.

We have demonstrated that the STSc method can be used as a tool to develop policy recommendations for transitions towards sustainability. In this brief paper we cannot sufficiently acknowledge the richness of various other methods to explore possible futures but we can claim that in comparison to these the STSc method has at least two strong features, notably:

- The method is based on a scientific theory of transitions. The patterns and mechanisms used in the method thus provide an insight into *why* certain linkages and developments occur. This renders better clues for policy intervention than more deterministic methods.
- The method not only pays attention to outcomes but focuses on transition *paths*. In contrast with most other methods this does not render simple diffusion paths but the scenarios show a variety of linking options and pay attention to qualitative change and leapfrog effects.

Compared to other methods, the STSc method has also less developed sides and disadvantages. In its present form, the method is not suited to compute the effects of (combinations of) policy instruments.

Furthermore, there is a subjective element in the scenarios presented. This partly results from the nature of transitions which are complex and undetermined which leaves room for subjectivity. In the scenarios above, for instance, we had to choose a limited number of niches in view of the limited overall length. A policy maker who is interested in another niche may still use the method to (let) explore its possibilities which may refine or amend the conclusions we have drawn here.

Thus, the method provides for flexibility which adds to its usefulness as an tool for a specific case that a policy maker (or other actors) may be interested in.

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