ECN

Energy research Centre of the Netherlands

The next 50 years:

Four European energy futures

J.J.C. Bruggink

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Preface

The Energy research Centre of the Netherlands (ECN) celebrates 50 years of technology development in the field of energy and environment. These past 50 years have been characterised by major transitions in technological focus, sources of funding and market orientation. ECN started out as a nuclear-oriented, government-funded, national laboratory with few industrial connections. We are now a market-oriented organisation with a broad portfolio of technologies addressing all major sources of energy and covering all stages of the research cycle from short-term implementation to long-term development. Our funding depends on servicing a wide array of public and private interests and we collaborate with universities and companies all over Europe.

Obviously, jubilees invite reflection, not just on past performance and success, but also on future challenges and opportunities. Those challenges and opportunities are closely related to European energy transitions in the next 50 years. On the occasion of our jubilee we therefore decided to take a closer look at the future of European energy innovation. We did so by developing a set of transition scenarios for European energy regimes describing the environment in which ECN must perform in the next 50 years. The scenarios contain four story lines connecting plausible global developments in world energy markets and climate change policies consistently with European energy regime changes and related national innovation pressures.

This document must be viewed as an essay on Europe's energy future. It demonstrates our commitment to contribute effectively to both European ambitions and Dutch economic interests. At the same time, it is intended as background material for an internal dialogue on the strategic choices facing ECN. It should be clear, that its contents do not necessarily reflect the opinion of the ECN management. In addition, we must mention that this study forms part of a larger project on European energy transitions, in which the story lines developed here will be quantified and spelled out in greater technological detail. We hope you enjoy reading this provocative exploration. If you feel inclined to oppose vehemently or support wholeheartedly some of the arguments ventured, we have succeeded in our intentions.

Ton Hoff

Managing director

Word of thanks

This study has been made possible by a financial contribution of the Ministry of Economic Affairs (EZ) for the project European Energy Transition Scenarios. I wish to thank the members of the EZ project steering group (Hugo Brouwer, Peter Aubert, Jaap de Jong and Simon Koomen) for their constructive comments on earlier drafts of this essay. Similarly, I have profited from the formative advice of the ECN project steering group (Armande van Duin, Harm Jeeninga, Gerard Peppink, René van Ree, Wim Sinke and Marcel Weeda). Obviously, they are in no way responsible for the final results nor are they necessarily in agreement with any of its conclusions.

Jos Bruggink

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Executive summary

In 2004 the Dutch Ministry of Economic Affairs published a white paper on innovation in energy policy describing a new approach to persistent environmental problems: transition management. Transitions are defined as processes of socio-technical evolution in which economic, institutional and technological structures develop interactively and change drastically in the long run. Transition management prescribes the way in which society-wide and complex system innovations can be guided deliberately towards goals of sustainability. So far, one important element of transition management has been implemented: the establishment of national innovation alliances between industry, research and local government. A recent review of energy transition policy by a high-level advisory commission compliments the Ministry on its pioneering role, but suggests strengthening the international component of transition policy. This essay concerns the European dimension of transition policy.

Transition thinking uses a multi-level perspective of social change processes. At the micro-level experimentation and demonstration is fostered in niche markets to promote innovation and establish a breeding ground for commercialisation of new energy technologies. At the meso-level successful innovations gradually influence the foundations of the energy system in terms of infrastructural configuration, institutional arrangements and company behaviour until a new energy regime emerges. At the macro-level societies define their basic values and broad ambitions in terms of sustainability. These three levels of social change processes are referred to as respectively the niche, regime and landscape level. They can be linked to geographical scales. From a European perspective the Netherlands can be viewed as a niche for experiments where variation is stimulated and adaptive capacity is maintained, while Europe is the selection environment that ultimately determines the success of energy technologies. At the same time, it is clear that the European selection environment itself is not immune to geopolitical and socio-cultural changes at the global level. Indeed, the European energy regime will evolve in different directions dependent upon those global changes and Europe's own ambitions at the global scale. This essay is based on the idea that the future of energy in the Netherlands will emerge as a result of anticipating on potential European energy transitions. To explore those potential European energy transitions is the purpose of this document.

Scenario analysis articulates our hopes and fears for the future. It should help in understanding the nature of the driving events and forces affecting the future and the uncertainties determining their potential impacts. Two major events would dramatically change the urgency and direction

of energy innovation in Europe: the arrival of a global peak in oil production and the failure of global climate change policies. The first part of this essay deals with the plausibility of such driving events. On the basis of a critical look at the arguments of the oil peak doomsayers and the environmental anti-globalists it is concluded that both events are plausible and would have major consequences for energy transitions in Europe.

Accordingly, the future course of European energy transitions is described in four contrasting scenarios:

- FIREWALLED EUROPE - Oil production peaks in the period 2010-2020. No viable post-Kyoto climate change policy emerges. The European energy sector turns back to coal and nuclear in the next 50 years.
- FOSSIL TRADE - Oil production follows oil demand smoothly in the period 2010-2020. No viable post-Kyoto climate change policy emerges. The European energy sector continues business as usual in the next 50 years.
- SUSTAINABLE TRADE - Oil production peaks in the period 2010-2020. Post-Kyoto climate policies develop effectively. The European energy sector turns to large-scale trade in renewables in the next 50 years.
- FENCELESS EUROPE - Oil production follows oil demand smoothly in the period 2010-2020. Post-Kyoto climate policies develop effectively. The European energy sector diversifies strongly keeping all options open for the next 50 years.

The major part of this essay concerns the storylines for these four scenarios at the global level of socio-political landscapes, at the European level of energy regime transitions and at the national level for innovation systems. As the names of the scenarios suggest the prospects for international trade in energy are considered crucial for differentiating European futures and allowing conclusions about actionable agendas for innovation.

Contrary to mainstream thinking a smooth transition to an increasingly sustainable world driven by climate change objectives and characterised by a gradual rising share of renewables is presently unlikely. In fact, an increasing part of the world economy is moving towards a FOSSIL TRADE scenario. Only strong issue linkages between climate change and poverty reduction, between trade and environment will lead to futures involving high shares of renewable energy as exemplified in the SUSTAINABLE TRADE scenario. Moreover, energy policy makers often act as if they believe in a FENCELESS EUROPE scenario, while in reality they might as well end up unexpectedly in a FIREWALLED EUROPE scenario.


The roles that Dutch companies can play on the European level differ fundamentally between these four scenarios. Making robust strategic choices for energy innovation policies in such contrasting scenarios is the challenge for strategic niche management in the Netherlands. In order to do so wisely, the Netherlands must follow the adagio “think globally, act locally”. It must not only consider European ambitions on the global scale, but it must also attempt to close the gap between technological innovations and profit opportunities at the local level. Alliances with regional economic interests are crucial in this respect. Given that the Netherlands is already acting as an energy gateway for Europe it has an excellent starting position. However, the future is likely to bring structural changes in energy value chains and only adequate innovation in different parts of those energy value chains can lead to success.

The final chapter contains four artist impressions of Dutch physical landscapes on the regional level that could potentially result from the four metaphorical landscapes described in the scenarios. The scripts for development of these physical landscapes concern specific technological innovations compatible with each of the four scenarios. These visionary examples demonstrate the concrete results of choosing for specific Dutch niches in the energy value chain including specific types of institutional innovation.

The Netherlands as European innovation niche

1 The Netherlands as European innovation niche

- Strategic niche management for European energy transitions -

1.1 The magic of transition management

Transition management as governance paradigm

The publication of the Fourth National Environmental Plan (NMP4) in 2001 signalled a break-through for the academic work of a group of Dutch social scientists active under the heading of transition management. The NMP4 presents a list of persistent environmental problems such as climate change, loss of biodiversity and resource exhaustion that can only be solved by society-wide and complex system innovations. Transition management provides a governance paradigm for addressing such persistent environmental problems. According to this paradigm transitions are processes of socio-technical evolution in which economic, institutional and technological structures develop interactively and change drastically in the long run. Transition management prescribes the way in which society-wide and complex system innovations can be guided deliberately towards goals of sustainability. Two major elements of such a transition approach are the stimulation of technological innovations in market niches through participative involvement of companies, research institutes and civil society and the creation of challenging visions for a sustainable future as a roadmap towards system innovation. The approach followed in this essay is inspired by and in line with the major tenets of transition thinking as developed by Frank Geels, René Kemp and Jan Rotmans.

Policy makers can make it happen

Thinking in terms of long-term transitions is not a new phenomenon in the social sciences. In fact the so-called evolutionary school in economic science considers the relation between technological change and economic growth the key research domain for their efforts. What is new in transition management is the pretension, that long-term, co-evolutionary processes in society are not an inescapable fact-of-life, to be understood in retrospect rather than be controlled pro-actively. Policy makers are no longer viewed as detached and clinical observers of sociotechnical change, they are considered as active participants able to promote technological innovation in the right direction. They cannot only offer a promising perspective towards sustainability; they can actively make it happen. And of course, the transition to a sustainable energy system is viewed as a key system innovation for global sustainability. The idea of energy

transitions thus magically transforms the bleak landscape for global sustainability into a promising avenue for action. It marries the sense of urgency with an equal dose of the sense of opportunity.

Multilevel perspective of transition theory

The theory of transition management is based on a multi-level perspective of social change processes. Three levels of change are distinguished:

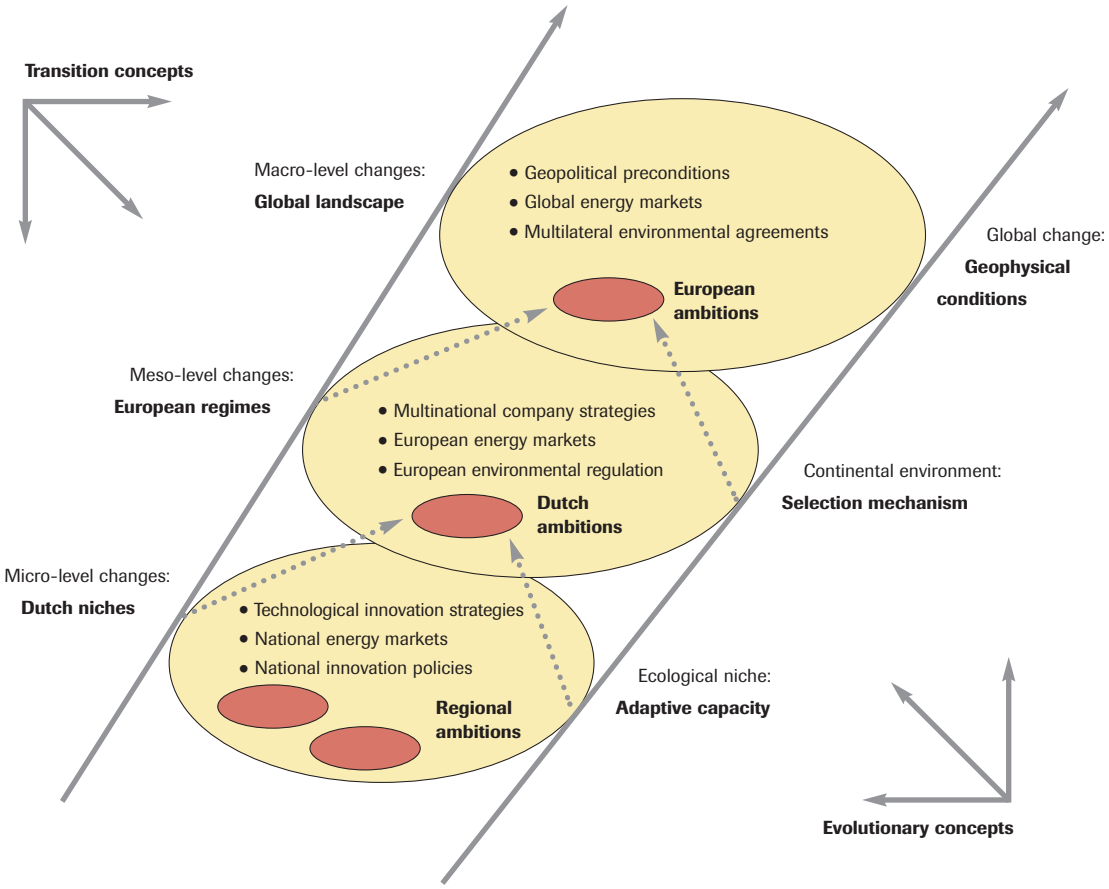
- At the micro-level experimentation and demonstration is fostered in niche markets to promote technological innovation and establish a breeding ground for further commercialisation. In evolutionary terms this is the level where variation and diversity originate; where adaptive capacity is developed.
- At the meso-level successful innovations gradually influence the foundations of the energy system based on infrastructural configuration, institutional arrangements and company behaviour until a new energy regime emerges. In evolutionary terms this is the level where selection takes place and innovations have to survive.
- At the macro-level societies define their basic norms and values, their broader ambitions and political goals. Transition theorists call this the socio-political landscape level. In evolutionary terms, this is the level where selection mechanisms are formed and propagated. This is where the limits and boundaries for possible energy regime changes are set.

Generally, transition theory stresses the importance of micro-level technological innovation for regime changes on the meso-level (technology push factors), but in the case of energy and environment, developments at the macro-level may be of equal importance in determining the direction of regime changes (demand pull factors).

Geographical scale and the multilevel perspective

The multi-level perspective of transition theory is clearly linked to the scale of changes. It is therefore also related to geographical scale. Although some technological innovations will be able to survive in geographically limited areas, they are unlikely to play an important role in regime changes if they do not form part of system changes affecting a larger geographical area. For energy system innovations the link between multi-level change processes and geographical scale may even be quite strong. Regional and national energy markets and regulation are increasingly dependent upon European and global energy markets and regulation. For the purpose of exploring Dutch strategic niches from a European perspective we will therefore link the multilevel perspective of transition theory with the geographical scale perspective of strategic niche management in Europe. In this respect micro-level technological innovations are supposed to take place at the national level, meso-level energy regime changes are supposed to take place at the European level and finally, macro-level geopolitical and cultural changes are supposed to take place at the global level.

Figure 1.1 Conceptual perspectives on strategic niche management



Strategic niche management for European energy transitions

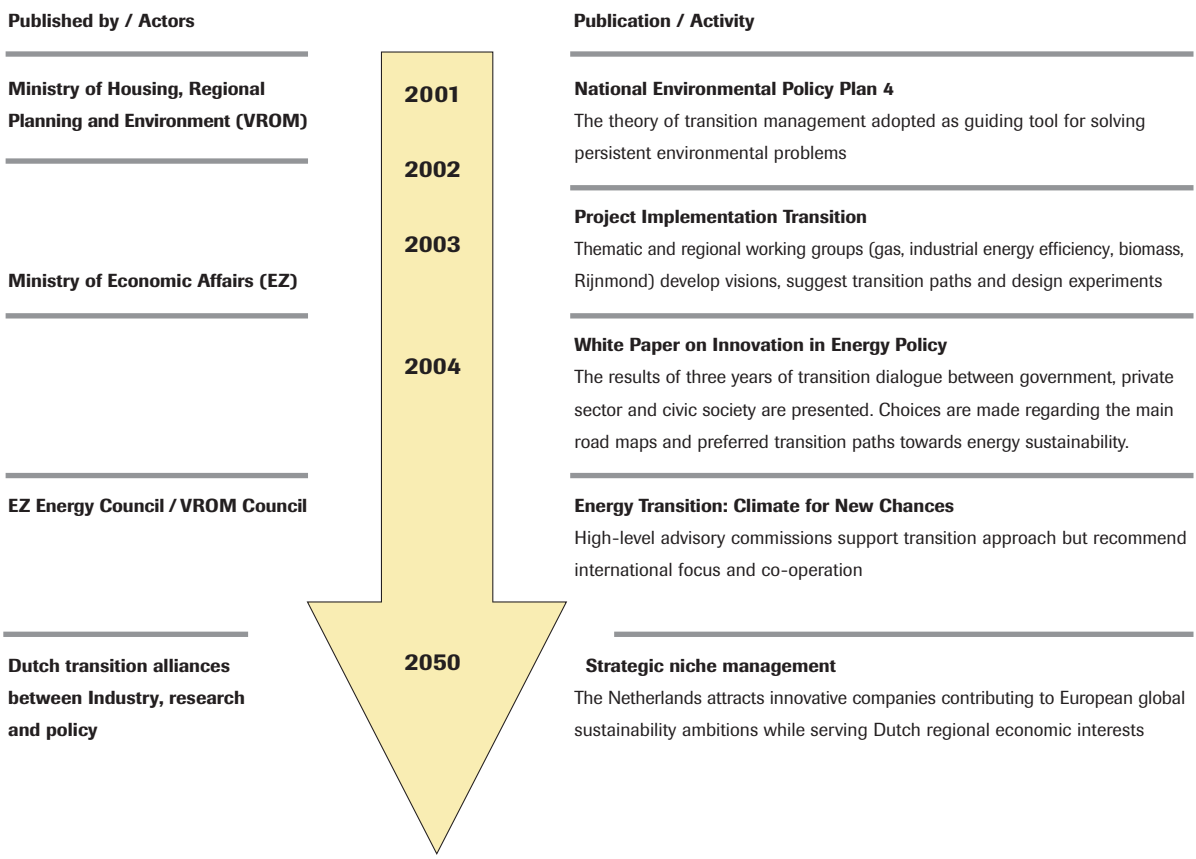
Strategic niche management can be viewed as the creation of an optimal balance between on the one hand protecting new technological options against premature failure in early stages of the innovation cycle while on the other hand gradually exposing them to inevitable market pressures at later stages of the innovation cycle. From a European perspective the Netherlands can be viewed as a niche for experiments where variation is stimulated and adaptive capacity is maintained, while Europe is the selection environment that ultimately determines survival and success. At the same time, it must be clear that the selection environment itself is not immune to geopolitical and socio-cultural changes at the global level. Indeed, the European energy regime will evolve in different directions dependent upon those global changes and Europe's own ambitions at the global scale. The future of energy in the Netherlands will emerge as a result of anticipating on potential European energy transitions.

1.2 Energy transition policy in the Netherlands

Dutch energy policy and transition management

The ministry of Economic Affairs is responsible for energy policy in the Netherlands. They have embraced the message and promise of transition management with vigour. As a first step they set up an intensive dialogue among numerous stakeholders to define jointly a set of so-called transition paths. A transition path describes the preferred technological innovation routes towards sustainability goals in the energy domain for the Netherlands. In early 2004 this participatory process culminated in a white paper summarising the present state of energy transition policy. It distinguishes a number of preferable transition paths clustered in five main roadmaps (green resources, alternative motor fuels, chain efficiency, efficient and green gas and renewable electricity). The report also outlines the policy steps ahead. The on-going second step involves the selection of transition experiments within each roadmap that are designed to learn how

Figure 1.2 Time line for Dutch energy transition policy



specific energy systems function in concrete projects. Preliminary feasibility studies by coalitions of private parties, research institutes and local government have been carried out and presently a tender is open for co-financing of actual implementation of transition experiments.

Strategic niche management will help to make the magic work

By the end of 2004 the VROM-Council and the Energy Council, two high-level advisory boards of the Dutch government, had jointly reviewed the transition approach of the ministry. The review compliments the ministry on its pioneering role, but suggests strengthening the international dimension of transition policies considerably. They suggest four different tracks for action: multilateral co-operation on the global level, pan-European co-operation at the community level, bilateral co-operation with European frontrunners in the transition arena and promotion of Dutch national economic interests where and when possible. In the light of these recommendations a closer look at European energy transitions in the next 50 years from the point of view of strategic niche management could help to strengthen the international dimension of transition policy and make the magic of energy transition management work.

1.3 Four transition futures for Europe

Scenario approach articulates hopes and fears

If the Netherlands wishes to take contrasting directions in European energy transitions into account, these directions can best be described in terms of alternative scenarios. The scenario approach offers a familiar toolbox for strategic analyses in the energy sector and is used widely by energy companies, planning bureaus and multilateral organisations. The scenario approach helps to understand the nature of the driving forces affecting our future and the uncertainties determining their potential impacts. Scenario analysis thus serves to articulate long-run hopes and fears. On the one hand, it helps to identify robust responses in order to reach desirable ends (developing so-called shaping strategies). On the other hand, it helps to initiate pre-emptive actions in order to prevent undesirable consequences (developing so-called hedging strategies). Finally and more modestly, it generates early-warning signals and helps management to rehearse for contingencies. These three goals should help in setting an actionable agenda for strategic niche management. Of course, the scenario approach is not appropriate for all kinds of management problems. It is only effective in case of vague, complex and long-term concerns with lots of turbulence and potentially disruptive impacts. That is certainly the case, when we talk about sustainability problems.


Driving events for technology development and energy transition

Two major discontinuities that would dramatically change the urgency and direction of energy RD&D and the prospects for new technology implementation are the arrival of a global peak in oil production and the failure of global climate change policies. The first event would undoubtedly lead to sharply rising and permanently volatile oil prices. This would dramatically increase the pace of oil substitution in the transportation sector and petrochemical industry. It would first lead to increasing pressure on expanding gas supply and ultimately enforce early and increasing reliance on either biomass-based or coal-based fuels. A peak in global oil production could arise because of a combination of surprises of a political or economic nature on either the demand or supply side or both in the decade 2010-2020. The second event would imply a continuing stalemate in post-Kyoto climate change policy negotiation leading to vanishing prospects for greenhouse gas emission markets and disregard for the CO2 emission reduction potential of new investments in the decade 2010-2020. These two events lead to bifurcation points with respect to market forces and regulatory impacts that are the key driving forces of the energy sector in the long run.

Outline of European energy transition scenarios

If we accept that the key driving events mentioned would steer the future course of European global ambitions in the energy sector in different directions, it is possible to venture opinions on the consequences for European energy transitions. These consequences can be described in four contrasting storylines.

- FIREWALLED EUROPE - Oil production peaks in the period 2010-2020. No viable post-Kyoto climate change policy emerges. The European energy sector turns back to coal and nuclear in the next 50 years.
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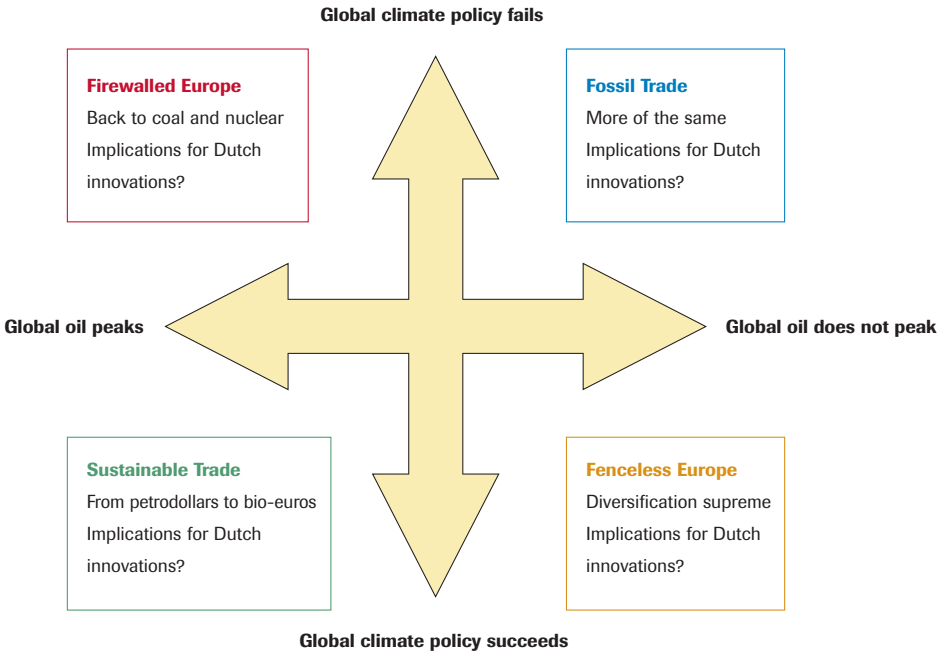
Figure 1.3 Survey of four European energy transition scenarios



Scope of present essay

In the next two chapters we will first take a look at the future of global energy markets and global climate change policies in order to defend the claim that major discontinuities here are plausible and have far-reaching consequences. The fourth and central chapter develops consistent, qualitative story lines of what those discontinuities mean for European global ambitions and European energy transitions. We then describe the general implications of the scenarios for innovation strategies. In the sixth and last chapter, we illustrate the general conclusions of the essay with four exemplary visions of concrete regional changes in the Netherlands.

The future of global energy markets

2 The future of global energy markets

- Why the doomsayers are right -

2.1 “When will oil peak?”: that's the question

The relevance of an oil peak for energy transitions

An oil peak is reached when global oil production starts to decline permanently. Oil peaks have been reached temporarily (late 1970's) or regionally (USA), but never globally and permanently. The past twenty years have seen a gradual increase in oil production (1,4% annual rate) at a more or less constant price level (in real US dollars). The oil peak question is of eminent importance, because if oil demand starts to outrun oil supply oil prices would become permanently volatile and persistently higher with dramatic consequences on the global market for other energy resources. Equally importantly, a global oil production peak would have a profound impact on the perception and behaviour of oil producers and consumers leading to structural changes in worldwide investment. The severity of such impacts on the global energy market would of course depend on the elasticity of oil demand and supply. The doomsayers are not only saying that an oil peak is likely in the short run, but also that the consequences will be grave.

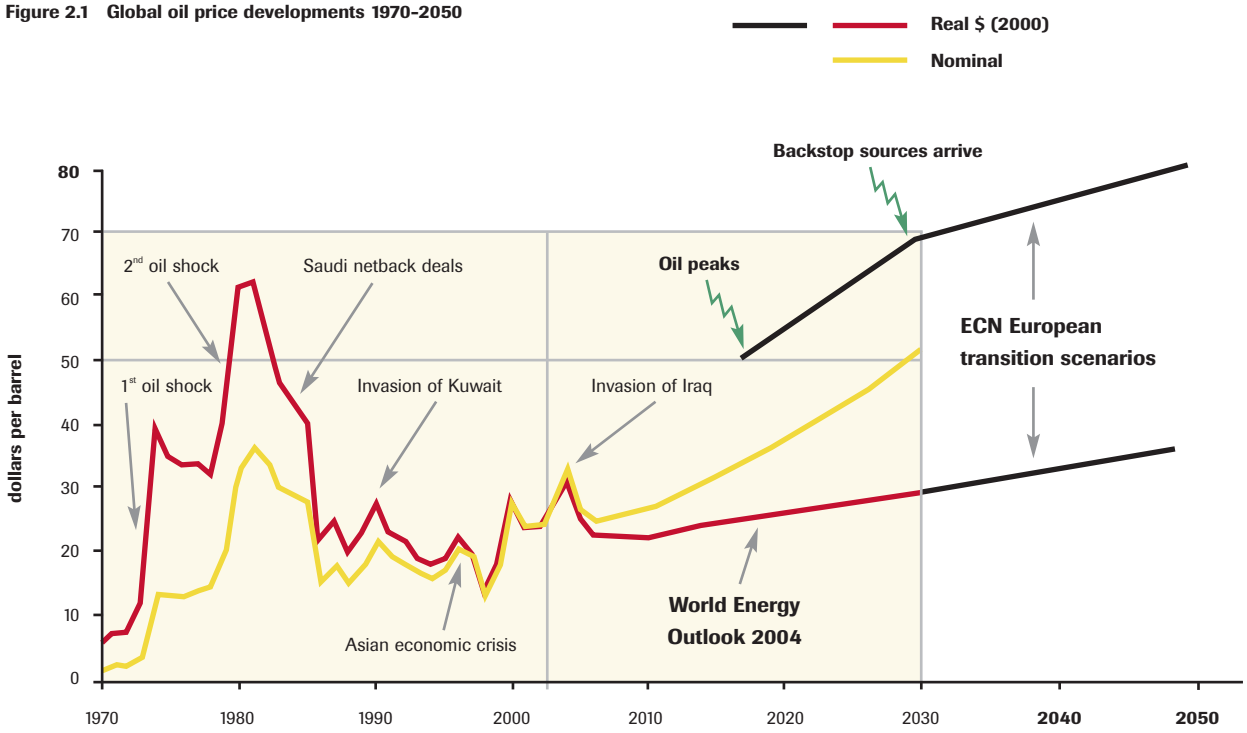
System innovations would be strongly stimulated

The opportunities for replacing the present functions of oil in transportation and as feedstock are generally high-cost and require long-term system innovations, while the opportunities for slowing production decline are equally high-cost and also require long-term system innovations. The arrival of an oil peak would change perceptions about the risks of fossil fuels and affect the investment climate permanently. The resulting shift towards gas and coal may have unexpected consequences and stimulate the search for unconventional alternatives. In addition, the high energy prices associated with an oil peak are undoubtedly the most promising route to close the gap between technological innovation and market implementation for sustainable energy systems. So, the timing of an oil peak is crucial to the chances of early energy transitions to sustainability, at least if we wish to harness market forces to bring them about. This makes a closer look at the possibility of an oil peak a prerequisite for seriously analysing energy transitions.

Presently the optimistic view prevails

Mainstream thinking about the future of oil is generally optimistic about the timing and consequences of an oil peak. The low level of oil prices in the past decade seems to bear this out although recent convulsions have seeded doubts. Exemplary is the forecast of the World Energy Outlook 2004 published by the International Energy Agency (IEA). According to their reference scenario oil production will grow uninterruptedly from around 80 million barrels per day (mb/d) now to some 120 mb/day in 2030, an average growth of 1,6% annually. Their main message is that global oil production will not peak in the next 25 years. Scores of publications repeat this optimistic point of view in some form or another. But there are some persevering pessimists that cannot be sidelined so easily given the sound empirical nature of their arguments. Their main message is that global oil production will peak in the coming decade. They do not represent the views of the oil establishment or multilateral organisations although they have established their own networks such as the Association for the Study of Peak Oil & Gas (ASPO).

Figure 2.1 Global oil price developments 1970-2050



Source: IEA and ECN

2.2 Fundamental differences in visions on future resource availabilities

Economists versus geologists

"The stone age did not end because we ran out of stones", is a favourite quip of economists in the field of natural resources. Scarcity according to them is not a physical, but an economic phenomenon. Markets and prices serve to balance the scarcity of nature with its utility for human kind. Long before we run out of oil, market forces will lead to changes in technology or demand, that make physical scarcity irrelevant. The economist's view is relevant in the sense that the geological reality of resource scarcity will eventually be reflected in the economic reality of price rises. Both economists and geologists actually agree on the fact that there will be a peak in oil production eventually. Their main disagreement concerns the timing of an oil peak and the severity of its impacts.

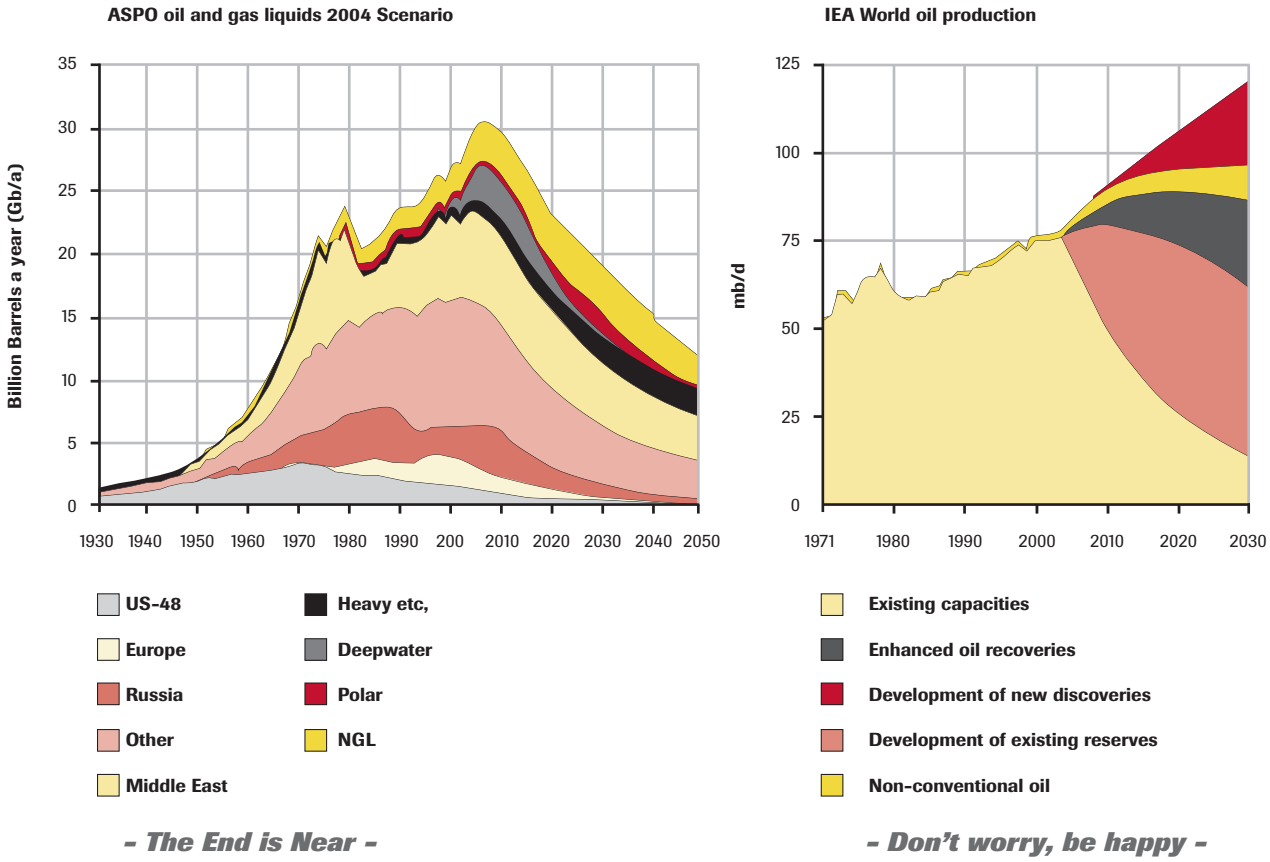
Tank-side versus tap-side arguments

Discussions about oil peaks are complicated because they involve not only arguments on the amount of available resources (tank-side arguments) but also arguments on the ability to bring those resources to market (tap-side arguments). The difference between pessimists and optimists can perhaps be best characterised in the light of their views of the relation between tank-side and tap-side arguments. The pessimists strongly believe, that information about oil reserves and resources (tank-side info) is highly relevant to judge the potential for future production (tap-side consequences). In fact, their most well known curves are based on establishing a unique and unilateral link between the two. They believe that past discovery and exploratory data are the clue to future production potential. Turning the tap wider open through ever expanding investments will not help to increase the flow of oil for any extended period if the tank bottom is in sight. The optimists on the other hand tend to think the other way around. They strongly believe, that information about oil supply and demand (tap-side info) provides the key to understanding oil reserves and resources. Turning the tap wider open will ultimately bring forth the reserves and resources needed to sustain higher production. Long before the tank bottom is in sight, prices changes will have smoothly induced the necessary technological innovation and fuel substitution to postpone an oil peak and avoid its supposedly dramatic consequences. While the pessimists focus on the (perceived) geological realities of tank-side arguments, the optimists focus on the (perceived) economic realities of tap-side arguments.

The ASPO prophecy versus the IEA verdict

The difference in opinion about oil supplies is not just an academic battle between different scientific disciplines, but has important consequences for the future of world oil markets. That is why optimists and pessimists are prone to mutual accusations of cognitive impairment, a condition in which people are unable to see things as they are, because it is not in their interest to see them this way. This is apparent from the widely divergent expectations concerning future oil production. According to the latest estimate of the Association for the Study of Peak Oil & Gas, the global oil peak will arrive in 2008. As stated before, the IEA assumes this is unlikely to happen in the next 25 years. Policy makers concerned about energy supply security tend to favour the IEA estimates, which are backed by the official seal of OECD energy consuming nations. Clearly, the precise prediction of ASPO seems unwise given the major uncertainties involved. On the other hand, there are also good reasons to view the unequivocal backing of the IEA expectations as unjustified.

Figure 2.2 The ASPO prophesy versus the IEA verdict on global oil production



2.3 Synopsis of doomsayers arguments

Arguments about ultimately recoverable oil resources

Generally, oil peaks refer to conventional oil resources, not to unconventional sources such as tar sands and oil shale that are subject to totally different laws of production. Unconventional oil is excavated, not pumped and therefore in terms of economic and environmental costs an entirely different product. For conventional oil (including gas liquids) the estimates from the US Geological Survey (USGS) are widely used and figure prominently in the IEA World Energy Outlook. The USGS estimates the ultimate recoverable amount of oil resources at 3345 billion barrels. Of this amount 717 billion barrels have already been produced. The remaining 2628 billion barrels consist of three categories. Proven oil in existing fields (959), probable oil in existing fields (730) and possible oil in new fields (939). The doomsayers argue that proven oil in existing fields may be vastly exaggerated and that the likelihood of finding oil in new fields is much smaller than assumed. In addition, they point out that the USGS data concern estimated means with a 50% probability. They consider betting on the planet's energy future with a 50% chance of overestimating the availability of oil resources is not a good idea.

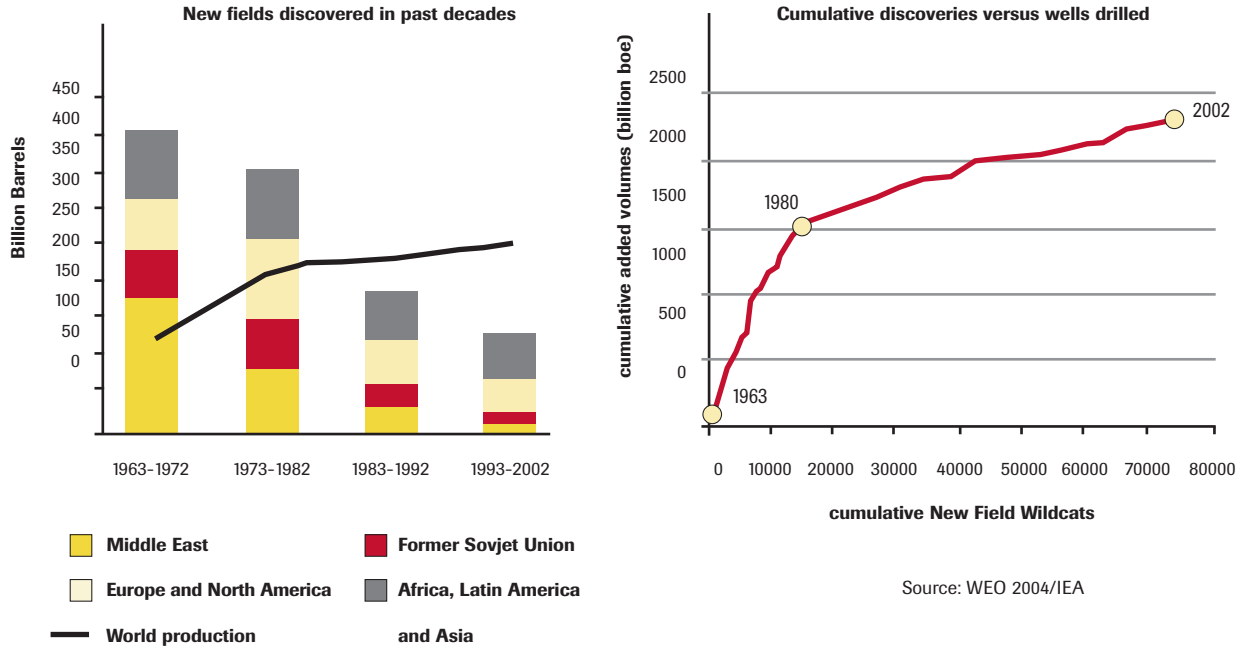
Spurious nature of statistics on proven oil in existing fields

According to ASPO, statistics of oil reserves in existing fields are a strange mix of national estimates driven by opportunistic OPEC bargaining objectives and non-OPEC company estimates driven by unduly restrictive financial reporting rules. OPEC nations have dramatically increased their reserve estimates in the late 1980's without perceptible increases in exploration activities. The reason according to ASPO is purely based on the wish to improve their bargaining position for production quotas. Equally mystifying is the fact, that they have not changed their estimates, regardless of cumulative production since revisions were made.
In contrast, multinational oil companies have revised their reserve estimates in the opposite direction although less dramatically. This downgrading is probably induced by stringent accounting rules of financial regulators.
The reserve data on existing fields that are often viewed as relatively uncontested are apparently dependent upon factors of a political and regulatory nature rather than geological and economic facts, Moreover, according to ASPO, it is likely that the OPEC estimates err far more on the optimistic side than can be countervailed by conservative company estimates.

Low probability of finding additional oil in new fields

Oil is found in fields of different volumes. According to the pessimists most large fields in the world have already been found. New additions to reserves are primarily a consequence of


Figure 2.3 Oil discoveries and wildcat wells



Source: WEO 2004/IEA

extensions of known fields, not of finding new fields. According to ASPO, such extensions should be back-dated to the time of original discovery of the fields in order to learn about new discoveries. Plotting additional oil found over time without reference to the actual date of first discovery of the field, leads to unfounded optimism about new discoveries. Indeed, graphs based on back-dating additions to the year of field discovery, indicate that oil companies are clearly having trouble finding new large fields. To underline this observation, a favourite graph of the pessimists plots the relation between exploration intensities (measured in terms of number of wildcat drills, that is drills outside existing fields) versus actually discovered resources. The resulting curve is called a creaming curve and it clearly pictures the increasing difficulty of expanding resources. The curve suggests that additional drilling is rapidly becoming ineffective. In other words, the curve may be nearing an asymptotic ceiling.

Arguments related to accessibility of reserves for oil majors

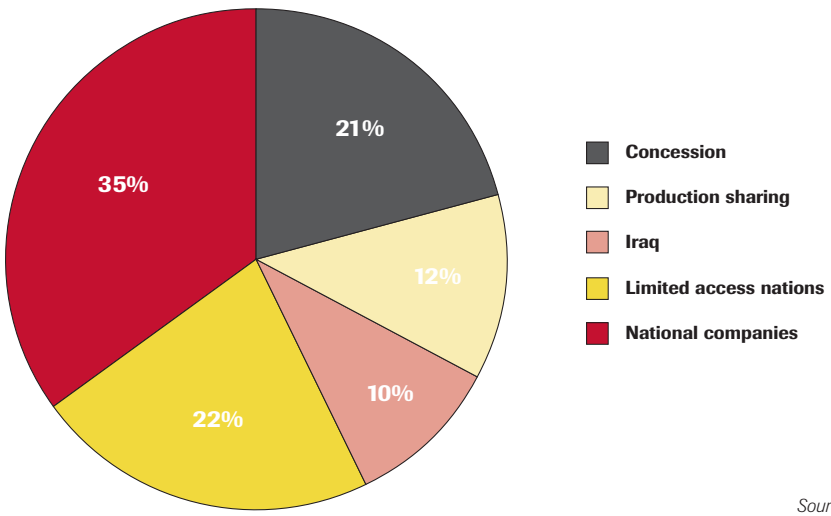
Remaining reserves are increasingly controlled by nations that do not provide unlimited access to the oil majors who possess the capital and technology to bring existing reserves to market in timely fashion to avoid major crises. In other words, even if the oil is there (proven

reserves), one can question the willingness and capability of owners to invest in additional production capacity to bring it on the global market in order to avoid global supply shortages. The oil majors are increasingly forced to access the least accessible and most expensive locations. Moreover, the political regime and regional strive of major oil producing nations are considered serious risks for oil majors and form an additional argument to explore and invest in deep water resources. Not only are those sources located outside the turbulent Middle East, they are also less prone to disruptions by regional disagreements about local benefits.

Arguments related to demand explosion

The demand for oil in OECD nations is almost exclusively for purposes of transportation fuels and chemical feedstocks. Since the oil crises of the seventies oil has almost disappeared from markets where alternatives are available and demand is more or less elastic (such as industrial process steam or domestic heating). There simply is no more room left for substitution. Moreover, historical analysis shows that that the accelerated economic growth in major countries of the world (particularly the BRIC countries - Brazil, India and China) has reached the threshold where mobility needs may grow explosively. This will undoubtedly lead to progressively larger claims on oil production from parts of the world that so far remained on the fringes of the global oil market. This is particularly true for China, which is aggressively trying to secure oil supplies for the long run by long-term contracts and foreign direct investments. The IEA World

Figure 2.4 Access of oil majors to existing reserves



Source: ICEP/Clingendael

Energy Outlook is remarkably conservative in this respect. They expect Chinese oil demand to increase from 5.2 million barrels per day in 2002 to 10.6 in 2020, an annual rate of growth of only 4%. Yet the Chinese passenger car fleet grew by 9% in the five years up to 2002. It is not likely to slow down substantially in the near future. The ownership of cars in China is around 10 per thousand persons. In Europe it is about 500 per thousand persons. Similarly, China has turned into the world's major workplace for low-tech mass production. This process of global industrial production redistribution is not likely to reverse in the near future and the impacts of double digit industrial growth rates on petrochemical feedstocks are unlikely to slow down any time soon.

2.4 Why the doomsayers are right

Question marks regarding conventional wisdom on resource availability justified

The arguments summarised above are not intended to demonstrate the unreliable nature of the IEA experts or the unsubstantiated views of oil economists. They are intended to demonstrate that there are major uncertainties regarding the feasibility of keeping oil supplies in line with continuing increases in oil demand. They support the hypothesis that an oil peak somewhere in the period 2010-2020 is far from impossible. While there are many events that could postpone an oil peak to after the year 2020, there are equally many events that could lead to an oil peak before the year 2020. In addition, the arrival of an oil peak will not mark the end of the oil era. It will only start a search for alternatives that is not any longer or not only motivated by climate change policies but strongly spurred by market forces. Those alternatives include early and forceful decisions about unconventional oil resources, which may indeed lead to new and higher peaks in oil production in the period after 2020. But ultimately, this course is likely to lead to far higher and more volatile prices for hydrocarbons in the medium term than would otherwise be the case.

Energy transition scenarios must articulate hopes and fears in a balanced way

Of course, it is not so simple to decide who is right in the sense of being able to predict an oil peak accurately. Fortunately, in terms of designing appropriate energy R,D&D strategies there is no need to decide about the most probable future. What matters most is to include a probable range of plausible futures. In this respect it seems increasingly clear, that the pessimists are right in the sense that an oil peak in the near future is indeed plausible and that it would be useful to consider the possible consequences for global energy markets and the resulting drive for system innovations. For the purpose of this study we are referring to the period up to 2020 rather than any one particular year. The doomsayers are right in the sense that scenarios with limited availability of oil and sharply rising prices deserve serious attention in terms of the consequences for European energy transitions and related energy R,D&D strategies. Conventional scenarios seem to focus exclusively on the articulation of hopes (continuing lack of resource constraints), but they should also focus on the articulation of fears (early arrival of resource constraints).


The future of
global climate
change policies

3 The future of global climate change policies

-Why the anti-globalists are right-

3.1 "Is globalisation the solution or the problem?" : that's the question

Profits, people and planet

Globalisation can be defined in many ways. In a narrow sense, it refers implicitly to just the economic sphere. The core phenomenon of globalisation at the economic level is the increasing interconnectedness of the world economy in terms of the volume of international trade and finance, the related role of multinational corporations and the rule of market forces. But in a wider sense it may incorporate many non-economic aspects that have to do with developments in the environmental and social sphere. When it comes to globalisation and energy transitions, three aspects of globalisation are of importance: economic (world energy markets, the profit dimension, energy availability), environmental (climate change, the planet dimension, energy acceptability) and social (poverty alleviation, the people dimension, energy accessibility). Sustainable energy transitions are supposed to benefit goals in each of these three different dimensions. Because energy is a dominant force in world markets, the prime cause of climate change, and an effective means of reducing poverty, energy transitions and sustainable globalisation are closely linked.

Markets are good servants, but bad masters

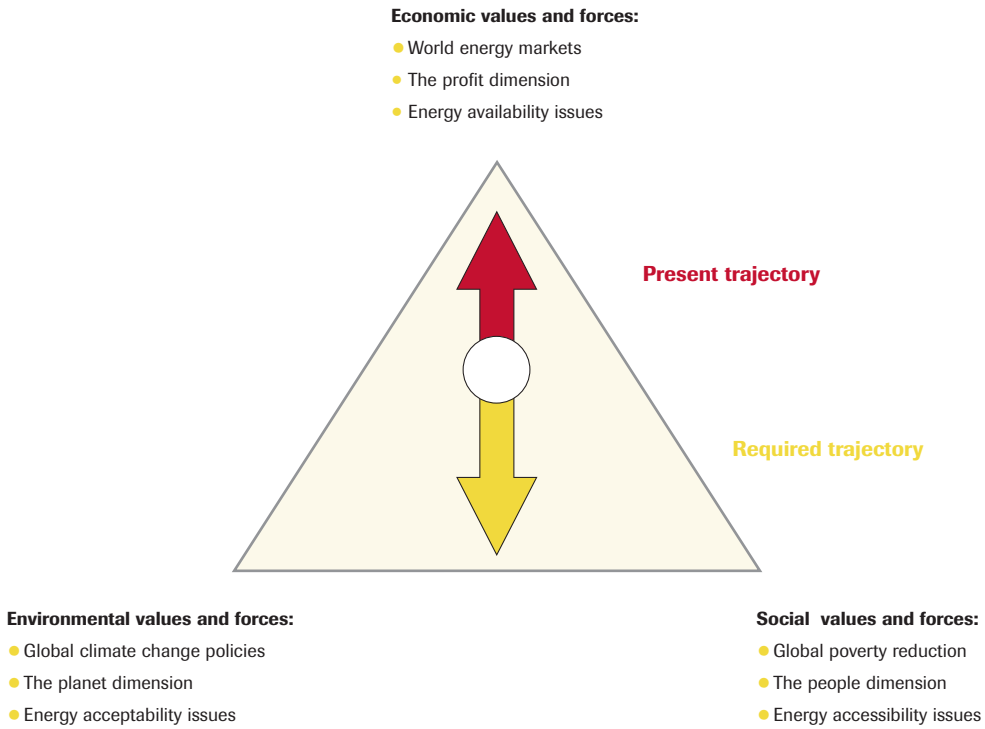
The anti-globalisation movement is an amalgam of activists ranging widely across the political spectrum and representing widely divergent advocacy groups. The thread that binds them together is the assumption that economic globalisation in its present form is detrimental for many worthwhile goals outside the immediate realm of profits. This assumption not only concerns the actual results of globalisation, but also the process of globalisation itself. In other words, regardless of the economic benefits attained, if they have been reached through undemocratic means (read markets, companies and profits), this is in itself a reason for opposition and worry. The democratic deficit will automatically impair true progress. While the champions of globalisation point at its actual economic benefits for a large number of the previously poor, the opponents are keen to focus on how those achievements have led to the empowerment and enrichment of the few (through rampant market forces) and the disenfranchisement and marginalisation of the many

(through deepening poverty barriers and degrading global environmental quality).
They often perceive market forces as an acceptable means to reach limited goals, but ultimately as a malfunctioning master of beneficial change in the domains of environment and poverty. When profits and markets run the process of globalisation its ultimate results are bound to disappoint. Markets may be good servants, but they are bad masters. According to the anti-globalists global governance should be fundamentally restructured or abandoned altogether for regional autonomy. The present course of globalisation makes it part of the problem, rather than part of the solution.

Success of economic globalisation tied to energy transitions

Notwithstanding the critical views of the anti-globalisation movement, most economists will point out that the existence of efficiently functioning global energy markets certainly contributed immensely to the success of economic globalisation in the past twenty years. This observation refers not only to the unlimited supply of transportation fuels for the explosive growth of the worldwide flows of materials and products. It also concerns the role of energy as an engine of growth. This role involves not only the unconstrained supply of primary energy sources, but also pertains to the much wider domain of energy equipment across the full spectrum of the energy chain from extraction to end-use.

Figure 3.1 The bottom line of sustainable globalisation



The energy sector has provided enormous opportunities for foreign direct investment and technology transfer, ultimately contributing to sustained economic growth in many countries worldwide. Moreover, changes in the energy sector have involved more than just a surge in investment and capacity expansion. In many countries, the structure of the sector in terms of governance and jurisdiction has changed dramatically in the wake of worldwide liberalisation tendencies. There has been a true energy transition involving not only technological innovation but also institutional change and new actors. Of course, the track record is decidedly mixed in the sense that with hindsight many energy projects and reforms leave much to be desired, but the grand picture is one of vast improvements when compared with past performance. According to this perception of reality, the present course of globalisation makes it part of the solution rather than part of the problem.

3.2 Fundamental differences in visions on future climate change policies

European climate change policy ambitions

The prevention of climate change has become a guiding goal for European energy policy. Europe has embarked on a courageous course in this respect. The European carbon emissions trading system is a unilateral act of faith in an eventually effective worldwide climate change policy. There are however presently no signs that the currently largest emitter of greenhouse gases (the US) or the future largest emitters of greenhouse gases (China and India) are in any way considering similar steps. Unfortunately, the prospect of those countries joining a revamped version of the Kyoto Protocol is gradually evaporating for two reasons. First, the realities of climate change are increasingly empirically evident, which will lead to a shift of emphasis from preventive action to adaptive action. This is particularly true for developing countries with limited financial resources and poverty-impaired adaptive capacity. Secondly, the US has unequivocally dismissed the European approach as basically flawed. Their argument is twofold. First they find the emphasis on immediate, absolute emission caps unduly costly. In other words, they consider the economic impacts unacceptable. Secondly, they find the unilateral action by developed countries detrimental to environmental integrity. In other words, they want developing nations to make commitments. The US is therefore following its own course based on enhanced technological innovation and bilateral agreements. If and only if Europe succeeds in changing the architecture of international climate polices in such a way that climate-wise development goals (in order to charm developing countries) and enhanced technological co-operation (in order to charm the US) are incorporated, will it find a promising continuation of its present course of gradually expanding international emission trading under internationally negotiated emission caps.

Relation between globalisation and climate change

The anti-globalisation movement is not primarily focussing on climate change problems. They are not forcefully present at UNFCCC meetings. They are primarily focussing on meetings of the WTO and other economically oriented gatherings of multilateral institutes such as the World Bank or the World Economic Forum. Climate change problems are considered as just one example of the malicious symptoms of economic globalisation. Yet climate change problems are key to confront the challenge of globalisation in two ways. First, except for the extreme localists on the left and the extreme nationalists on the right, most anti-globalists agree that solving climate change problems necessitates a "good" form of globalisation. It forces the movement more or less into constructive dialogue with the mainstream. Indeed, problems such as climate change are gradually splitting the anti-globalists in two camps: a minority of true anti-globalists and a majority of "alternative globalists". Secondly, it is increasingly evident that solving climate change problems effectively necessitates addressing other problems of globalisation. Only issue linkages between climate change and global poverty, between climate change and international trade can break the stalemate in international climate change policy negotiations. Such linkages confront the climate change community with the much wider and emotionally loaded issues of economic globalisation that upset and motivate the alternative globalists.

Issue linkages with poverty reduction and international trade regimes unavoidable

Present climate change policies are usually not a target of anti-globalist resentment. Indeed, the European drive to make the Kyoto protocol work has received the grudging blessing of many environmental activists. Whether this support will continue unabated is however far from sure. The Kyoto protocol has survived because it has an intrinsic escape route for nations hard-pressed to meet their targets through the Kyoto financial mechanisms of emission trading, joint implementation and the clean development mechanism. If this escape route evolves into the main course of action and domestic reductions and sustainable energy technology development in Europe are lagging behind, than the present course of climate change policies will perhaps be very cost effective in the short term, but its environmental integrity in the long term will be seriously hampered. Eventually, the Kyoto protocol may become just another example of the flaws of relying exclusively on the narrowly defined benefits of international trade and economic efficiency and the US and developing countries will find the alternative globalists reluctantly and tacitly on their side. Strong issue linkages with poverty reduction and international trade are necessary to safeguard the future of climate change policies. The prospects of successfully accomplishing such linkages are not altogether promising. The numerous plans of actions adopted at megameetings on sustainability have so far led to impressive intentions, not to impressive results.

3.3 Synopsis of anti-globalist arguments

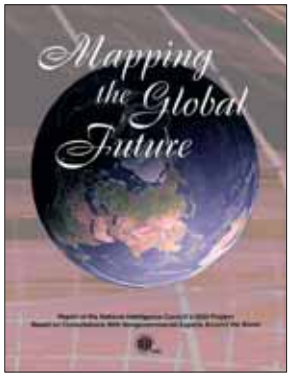
The undemocratic and inequity-prone character of globalisation

Economists tend to describe the benefits of globalisation in euphoric terms. Moreover, economists tend to find conflict and anger intrinsically baffling and are genuinely shocked by the vehement attacks on a core message of their profession: that market forces and international trade form the smoothest road to ubiquitous welfare. Not surprisingly, support for pessimistic and controversial views on the global future such as proclaimed by the anti-globalists is likely to come from a completely different corner. The most unequivocal support for the essence of anti-globalist arguments comes from a seasoned but reviled observer of global developments: the CIA. In late 2004 they published their latest report on global scenarios (National Intelligence Council, Mapping the Global Future), where they describe the challenges ahead for the US. The report is the result of an open process involving dozens of outside experts in addition to intelligence community experts. It focuses strongly on the long-term consequences of globalisation and acknowledges the destructive and undemocratic forces that globalisation has unleashed in addition to the beneficial aspects. The executive summary clearly reflects why the anti-globalists are worried. It states that "We see globalisation as an overarching megatrend …. Yet the benefits of globalisation are unlikely to be global … and the greatest benefits will accrue to countries and groups that can access and adopt new technologies." The summary also states that "more firms will become global … , more Asian and less Western in orientation. Such corporations will be increasingly outside the control of any one state and be key agent of change in dispensing technology widely." The report also stresses that "sharper demand-driven competition for resources, perhaps accompanied by a major disruption of oil supplies, is among the key uncertainties."

The race-to-the-bottom in international trade

Although the CIA shares some views of the anti-globalists on the undemocratic and inequity-prone aspects of globalisation, they are obviously not worried about another major theme of anti-globalist resentment: the consequences of unfettered international trade. As stated earlier the anti-globalists are not a homogenous lot and most of them focus their militant advocacy on one particular cause or another. The consequences of international trade nevertheless form a common theme irrespective of the primary causes for concern such as environmental degradation, human rights (including labour conditions) or poverty alleviation (including debt relief). International trade is conducted under a WTO trade regime that increasingly undermines rather than supports the few multinational environmental agreements in existence. The main reason is the increasing attention for non-tariff barriers to trade that concern national environmental regulation. The WTO is accused of adhering to minimalist regulation and defending the trading rights of environmentally less conscious traders.

Figure 3.2 CIA scenarios picture possible globalisation directions



Davos World *provides an illustration of how robust economic growth, led by China and India, over the next 15 years could reshape the globalization process -giving it a more non-Western face and transforming the political playing field as well.*

Pax Americana *takes a look at how US predominance may survive the radical changes to the global political landscape and serve to fashion a new and inclusive global order.*

A New Caliphate *provides an example of how a global movement fueled by radical religious identity politics could constitute a challenge to Western norms and values as the foundation of the global system.*

Cycle of Fear *provides an example of how concerns about proliferation might increase to the point that large-scale intrusive security measures are taken to prevent outbreaks of deadly attacks, possibly introducing an Orwellian world.*

This compels competing nations to lower rather than raise environmental standards and performance, ultimately leading to a race-to-the-bottom regarding environmental protection. Although presently non-tariff barriers with respect to energy and energy-intensive products are not a focus of attention, this could easily change when national climate change policies become more restrictive and costly and the demand for trade measures in order to protect climate-friendly national industries grows. In fact, in the case of climate change measures, we are presently at the bottom and it would be more correct to state that the WTO and international trade could become a serious deterrent for a race-to-the-top.

The deplorable consequences of multinational corporate behaviour

While most academic observers of the global environmental agenda tend to be confused by the impressive array of environmental villains from gluttonous northern consumers to corrupt southern governments, the anti-globalists are sure that multinational corporations are the main culprits. This seems odd, because typically, multinationals are better environmental and social performers than the average firm in both developed and developing countries. In many ways, they appear to be part of the race-to-the-top rather than the race-to-the-bottom. However, it is the indirect consequence of this admirable performance that explains the wrath of the anti-globalists: the relentless and uncontrolled erosion of local enterprise and employment in both developed and developing countries, the apparently wasteful explosion of global energy and transportation flows, the economic instability created by huge and volatile capital flows, the indiscriminate levelling of cultural diversity and individual identity by mass production and consumption, the global spread of materialist values and the concentration of wealth and power in the hands of corporate executives. Energy multinationals in particular have a long history of evoking unrestrained scorn. They are blamed for surreptitiously obstructing democratic reform in resource rich countries and unscrupulously prolonging the age of hydrocarbons. Moreover, past environmental disasters and recent financial mismanagement have scarred their image with the general public profoundly.

3.4 Why the anti-globalists are right

Question marks regarding the beneficial aspects of globalisation justified

The future of climate change is intricately linked with the future of globalisation. The anti-globalists are right in the sense that problems of environmental degradation, in particular climate change, will not disappear automatically as economic globalisation progresses. Indeed they may well worsen. Contrary to the hopes of at least some anti-globalists however, this does not mean that we could or should end globalisation altogether. Globalisation will continue in one form or another. It does mean instead, that efforts to get international climate policies of the ground may be doomed. In fact, there are presently just as many reasons to doubt an effective follow-up to the Kyoto Protocol as there are reasons to expect its extension into a next period of binding commitments. Furthermore, derailment of international climate change policies is not an isolated event. It would be indicative of a world in which political and social conditions would become prevalent that are not generally perceived positively in the democratic west (note the CIA scenarios). With respect to energy choices in Europe, such conditions would involve not just abandoning greenhouse gas emission reduction as the prime mover in shaping future European energy regimes, it would also involve a sharp twist towards goals of energy availability and security instead of energy acceptability in terms of global environmental impacts.

Energy transition scenarios must articulate hopes in a pro-active way

If we accept that climate change policies and globalisation are so intricately linked as the anti-globalists assert, it is perhaps wise to also address their concerns about the inequities of international trade and the role of multinationals. International trade should become a key theme for the dialogue on solving global climate change. Moreover, multinational companies are the key players, that determine the course of globalisation in general and the potential for success or failure of an international climate change regime in particular. European policy makers ought to take note of this message of the anti-globalists and reconsider their policy preferences in the light of on-going discussions about trade and environment. In fact, this is already happening, witness the fact that Russia was persuaded by the EU to sign the Kyoto treaty in exchange for support in joining the WTO. Energy policy makers should pay more attention to the wider benefits and dangers of international trade and how the benefits can be improved and the dangers diminished when dealing with sustainable energy futures. Sustainable energy scenarios must be explicit in this respect and articulate the hopes for an economically affordable and socially acceptable energy future in a pro-active way. Moreover, such scenarios should include an explicit vision on the possible role and position of today's energy multinationals in developing sustainable trade.

Four European energy transition scenarios

4 Four European energy transition scenarios

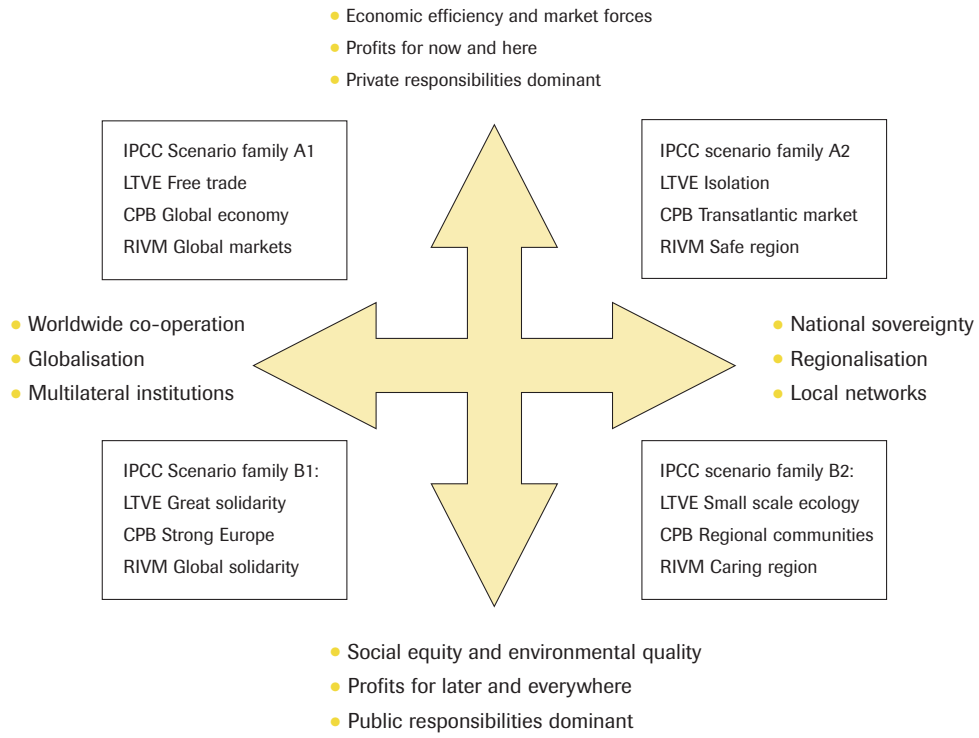
- Sustainability with or without fences -

4.1 Why not use existing story lines?

Basic features of available scenarios

A wide range of energy and environmental scenarios is available in the Netherlands. The Ministry of Economic Affairs (EZ), the Netherlands Bureau for Economic Policy Analysis (CPB) and the Netherlands Environmental Assessment Agency (MNP) all have developed their own long-term scenarios with a focus on sustainable development in connection with energy and environment. These scenarios all represent variations on the IPCC scenario families of the Special Report on Emission Scenarios published in 2000. The IPCC report sketches two basic driving forces in

Figure 4.1 Dutch story lines based on IPCC global scenario families



global development: the relative pace of globalisation versus regional fragmentation and the relative strength of profit-driven market forces versus social and environmentally driven public responsibilities. The rationale of this approach is based on two assumptions. First, when the pace of globalisation slows, the world will tend to fragment in regional economic blocks and global economic growth will slow down. Secondly, when public instead of private preferences would gain in strength regulatory forces will increasingly restrain market forces and again economic growth will slow down. These two axes of driving forces lead to four different global story lines. Although the Dutch scenarios mentioned use different terminology and different accents in describing their main story lines, they all inherit these basic features from the IPCC scenario families.

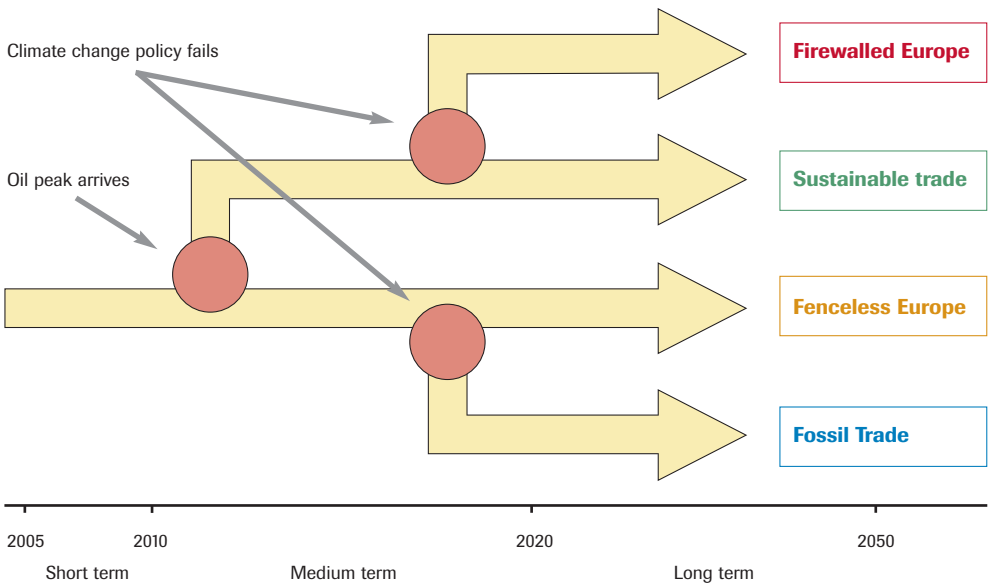
Energy transition scenarios should tell stories about trends ánd bends

In evolutionary theory discrete and catastrophic events are thought to have disturbed relatively stable equilibrium trends in fundamental ways eventually leading to new equilibria and new trends. These events cause bifurcation points in evolutionary development leading to a succession of punctuated equilibria. A similar line of thought can be followed when analysing energy transitions. Energy transition scenarios should therefore follow a theatrical approach to scenario development in the sense, that the unfolding plot is just as crucial as the final scene. The road-map leading to different equilibria is characterised by bifurcation points, where the plot changes. Discontinuities of one kind or another lead to system innovations. Once a certain track is followed however, it becomes difficult to change course and new trends are settling in. Technologies then become locked in. This phenomenon is referred to as path dependency.
We are presently trapped on a fossil fuels path with matching technological features such as the internal combustion car, central power production and hierarchically configured infrastructure. Only forceful events will lead to system innovation and entirely different energy regimes.
A short-coming of the IPCC scenario families and related Dutch story lines is that they do not contain such forceful events leading to clear bifurcation points. The underlying philosophy conforms to the general equilibrium theories of neoclassical economics where change comes gradually and smoothly. Energy transition scenarios must explicitly contain such forceful events leading to bifurcation points in order to adequately describe contrasting system innovations in the energy regime. A peak in oil production and the failure of climate change policy are such events and may lead to system innovations in the European energy regime. Moreover, as we suggested in the preceding chapters such events are quite plausible.

Energy transition scenarios concern co-evolutionary change rather than economic growth rates

A second feature of conventional scenarios is, that they are primarily driven by the rate of economic growth and structural change between major demand sectors. Volume changes and structural changes at the macro-level drive energy and environmental impacts. Cause-and-effect relations in conventional scenarios run primarily from economy to technology and not vice versa. This approach is highly relevant for reference scenarios in which energy system innovations are limited or at least not leading to major co-evolutionary changes in the economy. Energy transition scenarios on the other hand are intended precisely to focus on such co-evolutionary changes. In the case of the Netherlands such co-evolutionary changes are quite plausible. The future of the Rotterdam harbour and industrial complex is crucial to the economic growth prospects of the Netherlands, but it is not a direct result of such growth. The future of Rotterdam depends on whether Europe will go the way of clean fossil fuels or bio-based fuels instead and what this implies for Rotterdam. That is primarily a function of European energy regime changes. Similarly, the future of the Groningen gas cluster has a large impact on the Dutch economy, but again it is not a function of Dutch economic growth, but of the future of gas in Europe. Such co-evolutionary changes presuppose a strong link between technology innovation on the one hand and regional economic developments on the other hand. To describe such changes adequately, requires a different approach to scenario building than is the case in existing storylines.

Figure 4.2 Medium-term bifurcation points lead to long-term scenario divergence



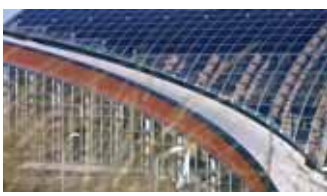
What is new in the design of ECN's European transition scenarios?

There are two reasons why translating broad global story lines into specific consequences for the deployment of energy technology is an unsatisfactory way of differentiating between energy futures. First, it remains unclear how the causal factors leading to different scenarios are able to break path dependencies and overcome lock-in effects in the energy sector. This requires a clear plot with specific events impacting on energy system innovation. Secondly, traditional approaches follow a unidirectional causal chain from economic growth to energy demand, from energy demand to energy supply and from energy supply to environmental impacts. Energy system innovations however are likely to require co-evolutionary changes where economic growth, technological change and environmental impacts are mutually interdependent. Apart from these analytical reasons, it should also be stressed, that the ECN European transition scenarios are intended to support actionable agendas. In this sense they must constructively help to formulate strategies either for shaping a more sustainable world or for hedging against a less sustainable world. The emphasis on the relation between trade, environment and equity is important in this respect.

4.2 Transition features of ECN scenarios

What are transition features of scenarios?

The arrival of an oil peak and the failure of climate change policies are not considered as independent events, that only affect technological transitions in energy regimes. In accordance with the co-evolutionary nature of transitions such events and their impacts must fit into a consistent pattern of changes of a non-technical nature that are taking place at the same time. We have distinguished three levels of such changes: the global socio-political level, the European energy regime level and the national innovation niche level. To describe the non-technical changes at each level in similar terms we will look at the same key transition features for each of the four scenarios. We will delineate below the general nature of these features in order to be able to use them without further explanation in the remainder of this chapter when describing the storylines of the scenarios.



Transition features at the global socio-political landscape level

To describe the global socio-political landscape and related European ambitions we will refer to connectivity and solidarity as the two key features leading to divergence in scenarios.

- Connectivity refers to the global flows of products, people and information and the resulting cohesion of socio-cultural lifestyles and perceptions. It is a feature of globalisation that refers particularly to the impact and importance of international trade and information exchange. From the point of view of global institutional arrangements connectivity concerns the future of the WTO and international trade policies. The present pace and character of connectivity may be restrained by social and environmental strings or heedlessly continued.
- Solidarity refers to the sharing of financial and technology resources worldwide in order to reduce poverty and equalise capabilities for capital and income formation worldwide. It is a feature addressing the need to confront the inequitable distribution of property and income creating capacities and to reduce the inequity-prone character of winner-take-all globalisation. International development aid policies and the future of UN development organisations are crucial in this respect. Socio-political changes at the global level may either enable or frustrate the implementation of international solidarity measures.

Transition features at the European energy regime level

To describe the changes in the European energy regime two transition features stand out: governance paradigms and the identity of the main game changers carrying transitions forward.

- Governance is a rather vague term indicating the mode of operation of governments. Governance paradigms dictate how governments set the rules of the game in dialogue with other players. The most important rules of the game in the European energy sector have to do with the balance between market forces and regulatory impacts. Events at the global level may change the ruling governance paradigm of diminishing public interference with markets and increasing private responsibilities. Attention for the individual freedom and basic needs aspects of liberal political philosophy instead of undue concentration on privatisation and liberalisation may result in more forceful measures to guarantee energy security in Europe and environmental integrity worldwide. Moreover, market forces and government regulation could become mutually enforcing agents of change rather than competing institutional arrangements for social control.
- Opportunities created for new actors or challenges emerging for old actors are important determinants for the pace and direction of energy transitions. The bifurcation points suggested in distinguishing European energy transitions have important consequences for vested interests in the energy sector and emerging new stakeholders. They may facilitate or hamper new roles for traditional actors or they may stimulate or prevent new coalitions across

traditionally separate economic sectors. Who will be the game changers shaping energy markets, is an important characteristic of European energy regimes. New actors could include both consumers citizens willing to venture into new energy using technologies or innovators-entrepreneurs willing to venture into new businesses.

Transition features at the national innovation niche level

The present European innovation system forms a network of divergent national innovation systems of increasing complexity. The configuration of this network may change dramatically in the next 50 years depending upon the challenges raised. Two features of this European innovation network are crucial in this respect: the interpretation and implementation of the subsidiarity principle in R&D policies and the funding mechanisms of community research.

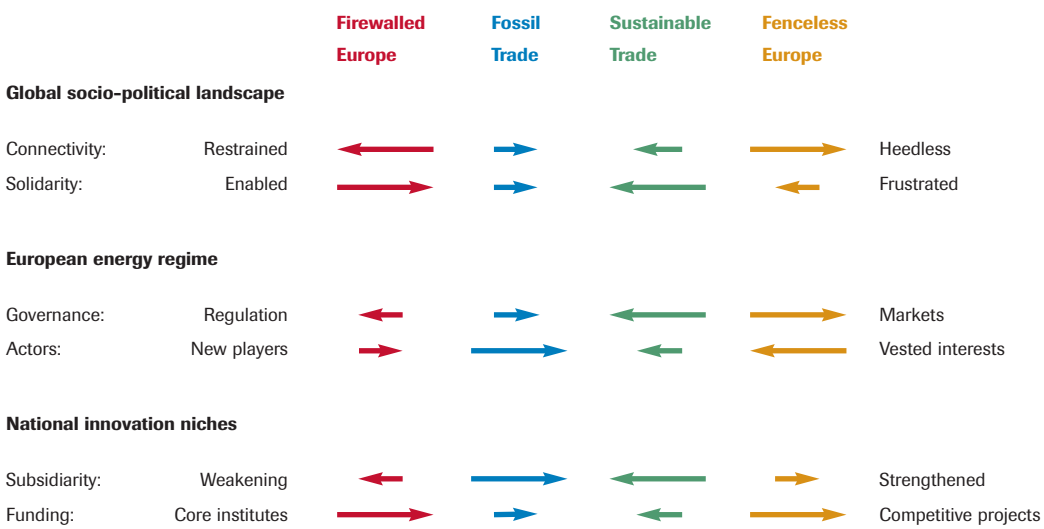
- Subsidiarity is a leading principle guiding R&D choices of the European Union. It implies that no R&D activities are implemented at the European level that could be equally well implemented at the national level. Application of this principle may lead to public free-rider effects in R&D, which could be particularly harmful when private R&D in liberalised markets is under pressure. The future role of national innovation systems depends on the way in which the subsidiarity principle survives.
- In the past decade there has been a tendency to prefer R&D funding on the basis of project-oriented, competitive tenders instead of on the basis of institutional core funding. Moreover, more and more public R&D programmes require co-funding. European programmes insist on national co-funding. National programmes insist on private co-funding. The complications of competitive funding with an increasing array of co-funding parties create an enormous amount of programming, monitoring and communication overhead, threatening the efficiency and effectiveness of public R&D. The future role of national innovation systems depends on the way in which funding mechanisms develop and this in turn is related to the degree and direction of innovation pressures in different energy transition scenarios.

4.3 Four global socio-political landscapes

FIREWALLED EUROPE: Europe focuses on security and internal cohesion

The arrival of a semi-permanent oil crisis and the breakdown of international climate change policy coincide with a world that appears increasingly unsafe and insecure to the average citizen of western democracies. Global connectivity is severely reduced. International trade stagnates and the WTO collapses. Security concerns also lead to restrictions on information flows and global travel. Europe tries to isolate itself selectively from unwanted foreign influences and dependencies. Firewalls try to effectively discriminate between the destructive and constructive. Bilateral ties with the European fringe may be established to increase the effectiveness of the firewall. The European block itself will remain compact and highly integrated. Steps to enlarge the EU are postponed or scrapped altogether. European ambitions on the global level with respect to sustainable development become weak and incidental. Solidarity suffers, not so much because of lacking compassion or need but because of deteriorating performance of multinational institutions. Development aid becomes disaster relief related to the increasing catastrophic impacts of a changing global climate combined with downward spiralling economies in parts of the world. Environmental policies increasingly focus on local and regional issues rather than global concerns. Europe will gradually drift to its own style of identity politics.

Figure 4.3 Assumptions about transition directions



FOSSIL TRADE: the global landscape unfolds with minor surprises

If the supply of hydrocarbons expands uninterruptedly and global climate change policies do not curb demand, there is a tendency to continue business as usual in the energy sector. Business as usual in the energy sector however does not imply that the global landscape remains unchanged. Global connectivity will increase, while present security concerns will remain. Solidarity will continue on its hesitant course. Europe loses its dominant economic position in global trade and growth and will be occupied by solving continental problems that are not primarily related to energy or environment. Bilateral ties between Europe and fossil fuel exporting nations will become extremely important, because Asian business approaches by national hydrocarbon champions will lead to new rules of the game, necessitating realignment of governmental and business interests in terms of energy provision. This is already apparent today in Asian moves to secure supplies including long-term contracts for unconventional sources and equity investment in pariah nations. Globally the trade in GTL (Gas-To-Liquids) and LNG (Liquefied Natural Gas) will expand very fast. The resulting shift in investment from oil to gas is already starting. Moreover, the coal-rich and densely populated nations of Asia will increasingly set the stage for innovations in fossil fuel conversion, possibly in line with coal-based developments in the USA and Australia. The European block itself will remain fairly diverse. Steps to integrate the EU socially and politically follow a steady but slow course. European ambitions on the global level with respect to sustainable development will continue, but remain largely ineffective. The environmental performance of multinational institutions will improve, but not in a revolutionary way. International climate change policies will strongly drift towards adaptation instead of mitigation.

SUSTAINABLE TRADE: Europe takes the lead in sustainable development

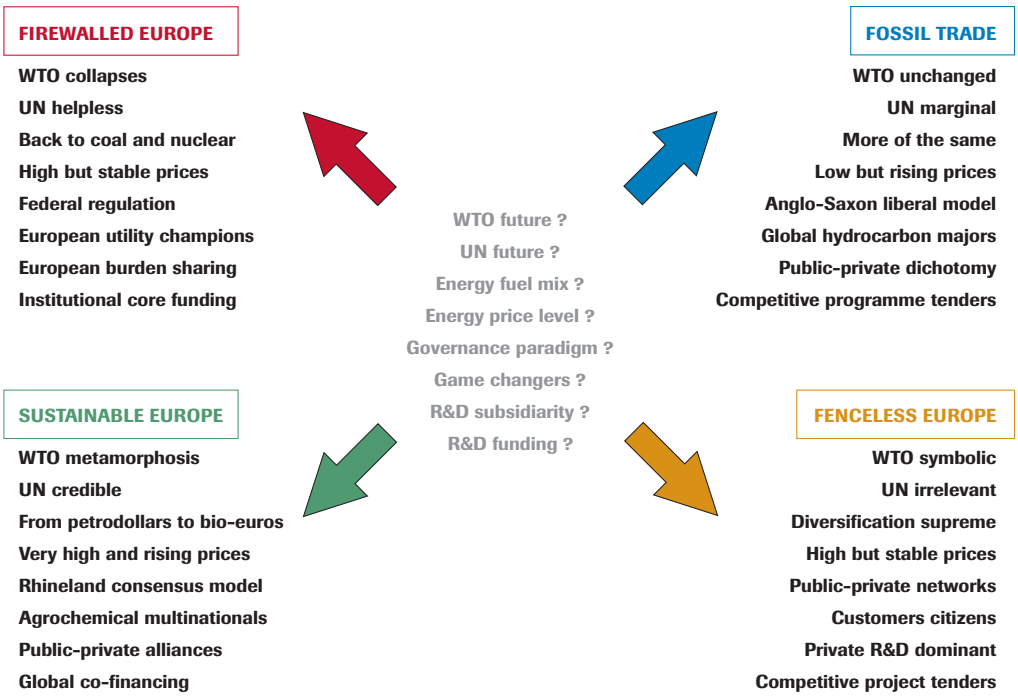
The arrival of a semi-permanent hydrocarbon crisis is not viewed as an unqualified disaster, but turned into a helping hand for commercialising sustainable energy technologies: global climate change policies become effective in promoting sustainable trade. The success of global change policies results from Europe's ability to diversify the initial Kyoto treaty into a mutually synergetic set of treaties. The simplistic focus on economic efficiency and greenhouse gas markets is widened including technologically oriented agreements with anti-Kyoto developed nations and trade-oriented agreements with Kyoto-respecting developing nations. A widening group of developing countries gradually gains perspective on lasting solutions to income insecurity and climate vulnerability, bringing the world a more equitable and thus secure future. This does not imply that fossil fuel supplying nations are ignored or punished, but that their role becomes less pivotal in safeguarding energy security and more conditional on environmental performance. Indeed, the coal-rich nations of the world will be prodded towards climate friendly innovations in

fossil fuel conversion, unless they wish to risk their trade position in the long run and hasten the early arrival of competitive sustainable energy resources. The European block itself will become more integrated, particularly on the social and economic level. European ambitions on the global level with respect to sustainable development are effective. European approaches to energy and environmental policies become instrumental in guiding the course of global institutional development. Globalisation becomes less contested and controversial. The performance of multinational institutions will improve in a revolutionary way. Agrochemical multinationals from Asia and Latin America challenge the oil majors. The need for stringent climate change adaptation policies remains modest.

FENCELESS EUROPE: bottom-up revolutions shape the global landscape

The unrestrained availability of fossil fuel resources at affordable prices leads to a sustained boom in global trade. The resulting widening of the spectrum of consumer-citizen preferences around the world breaks the present trend towards the indiscriminate levelling of cultural diversity and individual identity by mass production and consumption. Rich consumers in the developed West start to behave more like responsive citizens. They are willing to pay the price for improving sustainability if they can do so effectively and visibly in their local environment. Poor consumers in the South are not following the standard route of imitating the spending patterns of the rich in the West. Creative companies succeed in developing sustainable surprise solutions in the area of low-energy mobility, housing and appliances. Growing global connectivity leads to diversity instead of uniformity. The global spread of materialist values does not lead to cultural uniformity and homogeneity, but instead results in a plethora of new consumer options and the creation of viable pockets of new lifestyles that are inherently more sustainable. The trickle down effect of earlier ages is still effective, but instead of creating more and more uniform and unsustainable choices for increasingly larger sections of society, it now leads to diversity of sustainable choices and the fast evolution of sustainable communities in unexpected corners of both the developed and undeveloped world. Globalisation leads to cross-fertilisation of new lifestyles based on new products and services. This process of consumer-driven innovation is strongly supported by continuous progress in market-based climate change policies at the global level that increasingly crowd out fossil fuels produced without CO2-capture and storage. Security becomes a minor concern, because few nations, religions or minorities feel threatened in their development potential by global pressures. Solidarity is no longer an exclusive issue of government concern and public regulation, but happens as a natural consequence of citizen responsiveness to poverty alleviation and ecological safeguarding everywhere.

Figure 4.4 Transition features of European energy regimes



4.4 Energy story line in FIREWALLED EUROPE

Common Energy Policy shapes energy regime

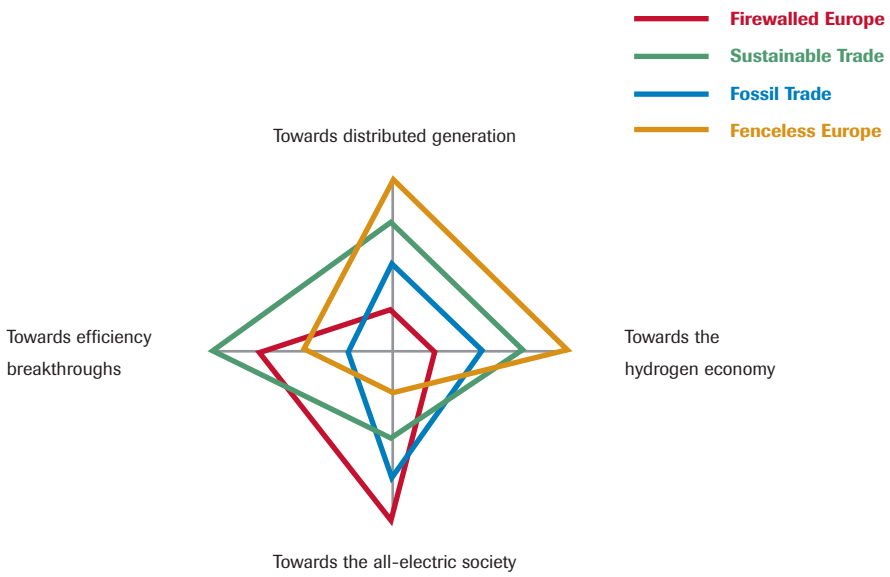
In terms of energy and environment, firewalls imply drastic measures to reduce dependency on energy resources traded with non-allied nations and an end to stimulating climate-friendly energy technologies that offer no advantages from a security point of view. In this atmosphere of crisis the former European focus on getting international climate change policies of the ground turns into a similarly determined drive for energy security purposes. Next to a Common Agricultural Policy, now revamped because of food security reasons, a Common Energy Policy is introduced. Targets are set for maximum food and energy imports. National fuel tax systems are harmonised and the EU introduces a regressive hydrocarbon tariff that effectively creates a floor in end-user fuel prices. The tariff initially leads to sharp increases in LNG (Liquefied Natural Gas) - and GTL (Gas-To-Liquids) fuel imports. The floor price rises to a level that facilitates the introduction of GTL-fuels and CNG-cars and ultimately coal-based liquids. The electricity sector turns to central power generation by nuclear, coal and off shore wind.

The competitive era for natural gas in power generation ends, because European gas prices increase dramatically. Few new energy actors appear on the scene and existing hydrocarbon multinationals and national champions in the electricity sector play a key role in financing new investments in protected, oligopolistic European markets. The EU introduces a form of security burden sharing by regulations enforcing and enabling long-distance deliveries of natural gas and electricity under specific conditions and allowing security premiums for companies creating strategically located redundant transmission and storage capacity. Problems of regional environmental quality and resource and waste infrastructure for the nuclear fuel cycle are addressed at the central European level.

Move towards an all-electric society with high energy savings

The emphasis on efficient, new central power plants combined with the high level of end-use prices for fuels will induce technological innovation towards sharply rising shares of electricity. The residential sector will move towards increasing shares of electric heat pumps in smaller and dispersed communities, while densely settled areas move towards district heating with waste heat from central power plants and coal-based industrial cogeneration. Progressive performance standards for buildings and equipment will limit the impact on absolute growth of electricity demand considerably. Technological convergence of innovations in energy and communication will help to raise end-use efficiencies in the long run. Stringent recycling policies help to curb

Figure 4.5 Benchmarking European energy regimes for system innovation hypes



material intensities. The potential for hydrogen in this scenario is purely based on its role in improving long-run supply security. There is no incentive to reform natural gas or to move from coal-based syngas to hydrogen. Only hydrogen from nuclear plays a slowly increasing role in the long run. The opportunities for distribution generation options are minimal except for the heat sector.

4.5 Energy storyline in FOSSIL TRADE

Transition towards a coal-based energy system

The continuing dominance of fossil fuels does not imply that the mix of primary sources and conversion technologies remains unaffected. The main impact on the European energy regime is a gradual penetration of coal in the European power market and industrial heat sector, primarily in the form of syngas. Pressures on the oil market are relieved by early commercialisation of gas-to-liquids in remote areas and the arrival of unconventional sources such as oil shale and tar sands. Biomass from waste remains competitive for stationary use for heat, but biofuels in transportation disappear from the market. Increased efficiencies of hybrid cars and the impossibility of finding alternative sources of government revenue for fuel taxes prolong the economic viability of conventional internal combustion engines versus fuel-cell alternatives. In the longer run, coal-based liquids from Australia and the US enter the European market. Rising temperatures because of severe climate change in this scenario affect investments in the built environment in later decades. The balance between cooling and heating demand is fundamentally altered ultimately leading to electrification in the residential and service sector where a dual distribution net for gas and electricity in many parts of Europe is no longer economically justified. In the long run some natural gas distribution networks are converted to syngas, which becomes the fuel of choice for industrial complexes and power plants. Offshore wind succeeds in maintaining a viable, but marginal role. Vested interests in the European utility sector and the global hydro-carbon industry remain dominant, although some early movers in industrial syngas production and coal-based heat and power cogeneration capture a share of the market. European energy policy focuses primarily on regional and local air pollution. The use of fossil fuels becomes increasingly clean in this restricted sense. Adaptive policies in the face of climate change completely replace mitigation policies.

Lock-in effects restrain structural changes

The FOSSIL TRADE scenario shows few pressures that would dramatically change the fuel and technology mix and lead to infrastructural revolutions. Lock-in effects lead to path dependencies

of energy technology development. The arrival of unconventional sources of oil and gas is easily incorporated in mainstream businesses. The gradual displacement of oil refineries by coal refineries remains almost hidden to end users in household and industry. The building blocks of the chemical industry remain more or less the same. Technology innovation is concentrated in the upstream side of the energy sector. The pressure to save energy is not supported by economic forces, although autonomous savings continue in line with historical developments. There is however a slow move towards the all-electric society.

4.6 Energy storyline in SUSTAINABLE TRADE

Aggressive environmental regulation creates new sustainable markets

The relentless price rise of CO2-credits on the internal market combined with sharply rising prices of fossil fuels lead to an initial boom in offshore wind and regional biofuels. Once niche markets prove successful new ventures in international trade of renewable resources are rapidly filling up the threatening gap between hydrocarbon demand and supply. New actors from the agricultural and food processing industry succeed in diversifying towards energy and challenge existing global fossil fuel players. Initially, biomass for both heat and power in one form or another dominates trade flows, but in a later stage biofuels from woody sources penetrate the mobile market and can challenge the first generation biofuels from oily sources, because of higher CO2-credits. Ultimately solar power imports from Northern Africa start playing an increasing role in the electricity sector. The BRIC countries (BRazil, India and China) are instrumental in helping to turn around the WTO towards an environmental race-to-the-top. In return for unlimited market access in Europe and the USA they comply with a new international climate change regime setting graduated long-term targets for CO2 reduction with low level fines as escape valve. This move is reluctantly supported by energy-intensive multinationals who wish to continue unrestrained operation on global markets that are increasingly dominated by Asian demand and supply factors. Both the USA and China/India invest heavily in carbon capture and storage and in nuclear in order to meet mitigation targets domestically. The transport sector in Europe becomes completely based on tax-free biofuels. Scrapping of the Common Agricultural Policy forms part of the deal with developing countries and helps to fill the resulting gap in the tax base. The growth of industrial energy use is slowed down because the demand for energy-intensive hydrocarbon-based bulk materials diminishes. New biomaterials capture a large part of the market and allow major breakthroughs in industrial energy saving, because they are based on entirely different process designs. Technological changes regarding the gas and

electricity fuel mix in the residential sector are relatively modest but extremely high prices stimulate both technological and behavioural changes leading to strongly reduced energy intensities in end-use.

Relentless energy conservation efforts save the day

The drive for renewable energy sources is matched by an equally forceful drive to conserve energy. The joint introduction of expensive, imported renewables and impressive, domestic savings keep the budgetary consequences for energy consumers in households and industry acceptable. A judicious combination of strong market forces coupled with rigorous regulation leads to technological breakthroughs. Hybrid vehicles become the norm and the residential and service sectors are enabled to align demand and supply loads without suffering in comfort. There is a tendency to distributed generation, but given the infrastructural needs of large-scale imports, some central conversion facilities remain crucial. Hydrogen occupies a niche market at the central level, primarily to provide flexible storage for excess electricity from offshore wind and imported solar.

4.7 Energy storyline in FENCELESS EUROPE

The customer is king, but environmentally caring

Vague notions of customers as kings have often motivated the move towards liberalization in the energy sector. Usually, customer preferences in the energy sector have so far been condensed to the dimension of low price and to freedom of choice between companies that appear only different at the margin given the uniform nature of kWh's and gallons of petrol. In the FENCELESS EUROPE scenario, energy markets change fundamentally in character, because fierce competition leads to market differentiation based on energy services containing a much broader package of product characteristics than delivered units of final energy. Such characteristics include installation and management of domotica options and centrally controlled appliances, a much more prominent role of environmental and social impact labelling and a much larger variety of mobility options. Moreover, by bringing technological choice on the client's doorstep consumers become co-producers of sustainable solutions, rather than apathetic follow-ers of environmental and social fashion at the corporate level. The creation of this diversified market in comfort, mobility and novelty is helped by along by creative policies for climate change mitigation. Moreover, energy innovations from all over the world are rapidly able to find niche markets for effective learning-by-doing. The ultimate consequences for this scenario of bottom-up revolutions are hard to describe in terms of fuel and technology mix. Clearly, micro-generation options and

small-scale renewable options such as solar cells are likely to be successful. The integration of public and private transportation will gain in importance with unpredictable surprises. The internal combustion engine will probably lose its central role, because sophisticated public transport alternatives and electric or fuel-cell cars will gain an early market share. The drive for major changes in the upstream side of the energy sector will be less pronounced in terms of fuel mix, because hydrocarbon resource scarcity is not an issue. The only major change will be fast penetration of carbon capture and storage, because high CO2-credits make this an attractive option.

Distributed generation becomes the norm

The fast penetration of generation options on the decentralised level and the relatively high level of savings in this scenario will place strong demands on infrastructure in terms of allowing reversible flows. Moreover, the tendency towards the all-electric society will be restrained, but the hydrogen economy may offer distinct advantages. The dominance of either electricity or natural gas networks may be tempered by preferences for local solutions based on dedicated mini-systems for heat, hydrogen or biogas. Storage solutions at the local level will also gain in importance, first in the heat sector, but ultimately for other energy carriers if unexpected storage innovations suddenly succeed. This is not unlikely given the enormous rewards for such innovations and the great diversity of companies involved in creative solutions worldwide.

4.8 Impacts on national innovation systems

FIREWALLED EUROPE: national innovation assumes European role

The deteriorating global situation leads to federal tendencies within Europe. Subsidiarity is no longer a major concern. R&D demands are articulated at the central level. The share of European publicly financed energy research increases. This is made possible by long-term agreements about European core-funding of national research institutions that are willing to submit long-term programme commitments based on European energy security priorities. Member states that succeed in offering high-quality facilities and competences and innovative demonstration projects for nuclear and coal or are willing to start promising experiments in recycling and materials efficiency will be able to attract substantial European funds. The new European utility champions now face a similar R&D environment as they did in the past on the national level before liberalisation. They co-operate intensively with the Euratoms of the future and are enabled by regulators to pass on R&D expenses to end-users. Smaller nations

attempt to find niches between the larger nuclear and coal institutes and are supported in their efforts by federal agencies looking for a balanced sharing of R&D costs and revenues across countries.

FOSSIL TRADE: dichotomy between public and private research remains

Global fossil fuel multinationals are again investing heavily in R&D for two reasons. They are no longer worried about the long run potential of fossil fuel because of climate change regulation and they are increasingly challenged by national fossil fuel champions from the developing world who backed by public financing and political leverage are increasingly penetrating their former dominions. Fierce competition for advanced fossil fuel technology dominates private R&D. The challenges for publicly financed R&D are less clear at the European level. National priorities of one kind of another remain the dominating guide for European research and the status-quo of the subsidiarity principle remains unchanged.

SUSTAINABLE TRADE: global co-operation creates new R&D niches

The European lead in promoting global sustainability implies a drastic shift in R&D priorities. Instead of focussing almost exclusively on establishing a European Research Area, global technological co-operation becomes the centre of attention. This is a result of on the one hand charming the US with a technology-instead of market-oriented approach to climate change mitigation and on the other hand charming the developing countries with development-oriented energy initiatives. Rather than supporting national initiatives based on the subsidiarity principle, co-funding of global initiatives becomes the norm. The funding mechanism includes a larger mix of instruments running the whole gamut from competitive project tendering to institutional core funding. Public-private alliances become much more important in order to close the gap between innovation and profits at an early stage, particularly in developing countries. New multinationals diversifying from the agricultural and chemical domains play a strong role in opening up new R&D niches. On the European level, some co-funding of national initiatives remains where it concerns breakthrough technologies for energy conservation with European potential.

FENCELESS EUROPE: new energy valleys lead to surprises

Public funding at the European level is in retreat and private R&D funding is regaining ground. Moreover, fierce competition worldwide shrinks the potential domain of pre-competitive R&D. The smaller scale, integrated design and client-specific nature of equipment and services lead to early learning-by-doing investments. The energy sector shows tendencies formerly observed in the ICT-sector. R&D demands are no longer articulated by environmentally conscious governments or vested energy interests, but by environmentally conscious customers. Outside venture capitalists rather than established firms determine the pace and direction of research and development. Firms specialising in specific components or services start to cluster regionally, not just in Europe but also in Asia. Technological surprises become the norm rather than the exception. The remaining European R&D funds go directly to private enterprise for innovative demonstration projects and are always based on competitive tenders.

Implications for innovation strategies

5 Implications for innovation strategies

- Think globally, act locally -

5.1 Finding a robust portfolio of technologies

Making robust strategic choices in technological innovation

The term strategy is a popular item in the vocabulary of self-respecting managers. It is meant to indicate that they are surely focussing on the essence of long-term survival and performance. Strategic choice in energy innovation is often viewed as a search for robust technologies. Robust technologies are defined as technologies that play a crucial role in a broad rather than narrow subset of possible scenarios. In practice this is very difficult, because scenarios are supposed to picture a broad spectrum of futures and few technologies are likely to play a pivotal role in all of them. The energy scenarios just presented affirm this conclusion. So robust strategic choice in energy innovation really amounts to finding a robust portfolio of technologies instead of finding robust technologies. This seems an evasive approach to strategic choice, because obviously the next question concerns the optimal composition of the portfolio. What criteria are we to use for defining an optimal portfolio? Classical criteria are often based on finding a good balance between short-term, incremental research and long-term, fundamental research and creating sufficient synergies between research topics in order to make investments in facilities and competences effective. On the basis of the European energy transition scenarios presented additional criteria seem relevant. Those criteria concern the position of research and development in the energy value chain and the institutional rather than technological aspects of national innovation systems. Before discussing those criteria however, a few general observations on the lessons from this scenario exercise are in order.

Combining shaping and hedging strategies

Contrary to mainstream thinking a smooth transition to an increasingly sustainable world driven by climate change objectives and characterised by a gradual rising share of renewables is highly unlikely. In fact, an increasing part of the world economy is presently moving towards a FOSSIL TRADE scenario instead. Only strong issue linkages between climate change and poverty reduction, between trade and environment will lead to futures involving high shares of renewable energy as exemplified in the SUSTAINABLE TRADE scenario. Otherwise, Europe will drift towards

a FIREWALLED EUROPE or FENCELESS EUROPE scenario depending on events in world energy markets. Dutch innovation strategies should not follow mainstream thinking blindly if the Netherlands wishes to play a role in setting the European energy agenda while contributing to Dutch regional economic interests. To do so wisely, two types of pro-active strategies in anticipation of potential developments in Europe must be combined. For potential developments in less sustainable directions as exemplified by the FIREWALLED EUROPE and FOSSIL TRADE scenarios we must concentrate on hedging strategies aimed at defensive r&d options that could ultimately limit the environmental and social impacts of less sustainable European choices. Such hedging strategies typically concern breakthrough technologies in energy saving, the environmental risks of nuclear energy and add-on fossil fuel technologies for carbon capture and storage. For potential developments in more sustainable directions as exemplified by the SUSTAINABLE TRADE and FENCELESS EUROPE scenarios we must concentrate on shaping technologies aimed at offensive r&d options that promote the efficient use of new natural gas options and renewable technologies in a changing infrastructural architecture. Such shaping strategies typically involve a wide spectrum of energy innovation in the energy value chain from global supply and conversion to local demand and end-use.

Smoothing the hype and disappointment cycle of energy system innovation

Solutions for energy problems tend to follow a hype and disappointment cycle concentrating on specific technological solutions. This phenomenon can be readily explained by the realities of researchers looking for funding on the basis of exaggerated claims of technological break-throughs just around the corner and opinion makers looking for promising opportunities to get public attention with simple and immediate solutions to complex and long-term problems. The resulting marriage of interests between technological product champions and kings of exposure often lead to early divorce and public confusion. Initial bliss is soon replaced by cynical attitudes and rising doubts. On the higher abstraction level of future energy system innovations there are a number of candidate energy transitions that figure prominently in energy policy discussions. Energy regimes are supposed to benefit from massive moves towards the hydrogen economy, towards the all-electric society, towards distributed generation or towards break-through savings technologies. It is true that European energy regimes will tend to drift in different directions with respect to these general system characteristics. The hydrogen economy has a better chance in a FENCELESS EUROPE or SUSTAINABLE TRADE scenario. Similarly, the FIREWALLED EUROPE and FOSSIL TRADE scenarios may be more conducive for an all-electric society. Nevertheless, even in this scenario study of wide ranging energy futures, the overall picture is far more complex and no single feature provides the magic key to future performance in terms of sustainability. Rather than following the hype and disappointment cycle of energy system innovation


closely, energy innovation strategies should aim to smooth such cycles. Constantly shifting R&D resources on the basis of such cycles leads to wasteful turbulence in the development and use of experimental facilities and human resources.

5.2 Contributing to European ambitions while serving regional economic interests

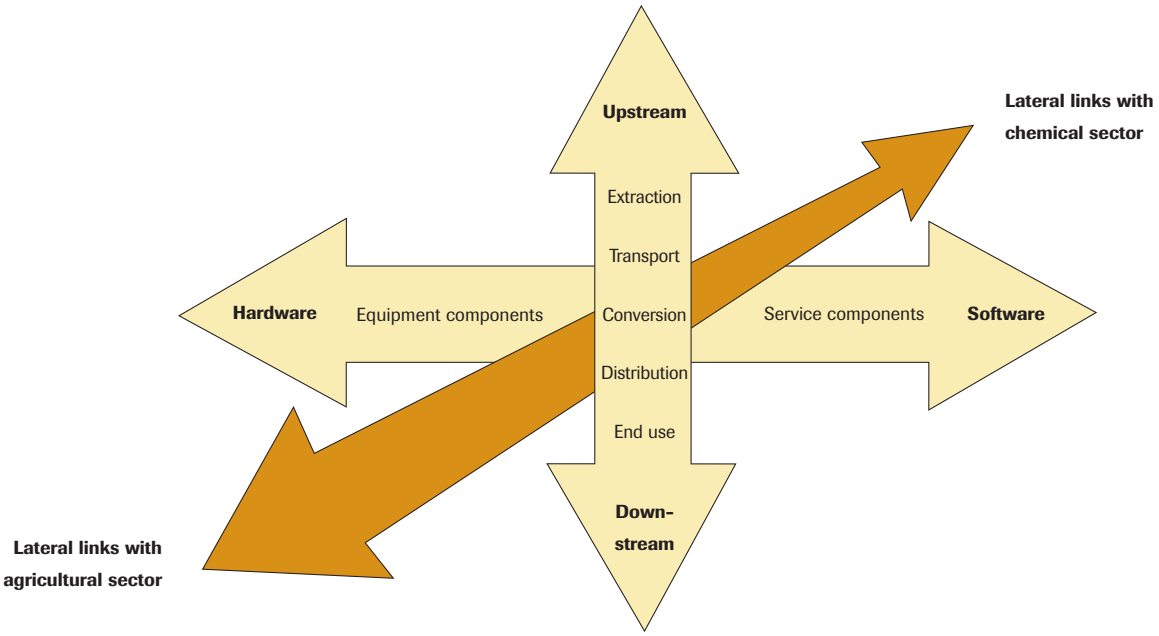
Need for thinking globally while acting locally

In the past 50 years energy innovation in the Netherlands was primarily guided by Dutch priorities and ambitions. For the next 50 years this will no longer be the case. The future of energy innovation in the Netherlands in general should emerge as a result of anticipating on potential European energy transitions and related ambitions. Strategic management for the next 50 years however requires not only a vision on how the Netherlands could contribute to the realisation of European global ambitions, but also efforts to close the gap between R&D and implementation more securely on the national level. In the domain of energy and environment there may have been a growing sense of urgency, but the sense of opportunity is not developing at equal pace. The global proliferation of energy and environmental problems is not resulting in a global blossoming of new energy and environmental business ventures. If the Netherlands wishes to play a key role in European energy transitions, it will certainly help if it succeeds in bridging the gap between innovation and profits more successfully. Fortunately, the Netherlands is already playing a key role in the European energy regime, because of its prominent position in hydrocarbon markets. It is a major supplier of European gas and a major hub in the logistic and conversion chains of crude oil. Moreover, the Netherlands is keen on taking up a frontrunner position in European energy transitions towards sustainability. If the Netherlands succeeds in forming promising alliances with regional economic interests relating to energy, it is well placed to serve European global ambitions. The adagio “think globally, act locally” summarises the essence of this intention.

The three dimensions of the energy value chain

Energy flows move from sources to sinks along a continuous chain involving extraction, transportation, conversion, distribution and end-use. In each step of the chain companies add value and earn profits. This is one dimension of the energy value chain, which we will refer to as the vertical dimension in accordance with the terms upstream and downstream. A second dimension of the energy value chain refers to the services and equipment involved in specific processes along the chain, which we will refer to as the horizontal dimension. This concerns the

Figure 5.1 Dimensions of the energy value chain



hardware and software (in a broad sense) supplied at each step of the vertical chain. R&D activities should help companies to increase the value added in successive steps of the chain and for specific hardware and software. Looking far into the future, there is a third dimension of the energy value chain having to do with the increasing importance of links with formerly separate value chains such as agriculture and chemicals. This third and lateral dimension complicates R&D choices, because the nature of such lateral links is uncertain. Choosing a robust portfolio of technologies for the future has a lot to do with preferred positions in this three-dimensional space of energy value chains, because future European energy regimes will involve major transitions in value-added along the different chains. In the past Dutch energy R&D activities have been characterised by a portfolio of technological innovation more or less concentrated in the conversion and hardware parts of the vertical and horizontal axes. One way to develop a robust portfolio of technologies for the next 50 years is to explore more closely how Dutch initiatives may contribute to value added in other parts of the energy value chain.

Application for the Netherlands

From the point of view of possible European energy ambitions in the next 50 years as described in the scenarios presented important shifts in value added along energy chains are likely. Three types of change are particularly relevant for the Netherlands. First of all, a shift from hydrocarbon to renewables or coal such as in the SUSTAINABLE TRADE or FIREWALLED

EUROPE scenarios will have important implications for the upstream part of energy value chains. Clearly, mainport Rotterdam could claim a pivotal role for Europe in this respect, if it is able to attract new actors in the biomass or coal chains. Moreover, lateral links with the agricultural and chemical value chains may help energy outsiders to compete successfully. Given the strong international position of the Dutch agricultural and chemical sector, such lateral links of value chains are of particular significance for the Netherlands. Secondly, all scenarios indicate an important role for natural gas albeit it may be for just a decade or two. The Netherlands provides a substantial share of European gas and shows the highest penetration of gas in Europe. This offers attractive opportunities for new niches of value-added creation. However, the way in which new value-added could be created may be very different. For instance, in the FIREWALLED EUROPE scenario the security premium of European supplies could become very high, while in the FENCELESS EUROPE scenario the value gains must be made on the other side of the value chain where the preferences of end-users count. Moreover, priority end-use sectors differ between scenarios. The present focus on central power and residential heat may shift dramatically, for instance towards mobile uses or to micro-generation.
Gas networks also allow easy hybridisation through introduction of multiple gas sources (syngas, hydrogen, biogas), a form of flexibility that could improve the competitiveness of advanced gas networks versus electricity networks. Finally, it is likely that important shifts along the horizontal axis will accompany shifts along the vertical and lateral axes. In particular, the share of value added in hardware components is likely to decline relative to the share of value added in software services. System services and ancillary services become more important when the penetration of renewables increases or efficiency standards rise. Moreover, the integration of technological innovations with end-use behaviour will become more important. Learning-by-doing for integrated systems is much more complex than testing hardware components and processes. Generally, early experiments at the local niche, in specific municipalities or industrial parks which sustainability ambitions, may help in identifying new services and business opportunities with a European potential.

Preparing for institutional innovation

One of the main lessons of transition theory concerns the required co-evolution of technological and institutional systems. This lesson is not only important for analysing the transition towards alternative European energy regimes, but also for determining national innovation strategies in a changing selection environment. In particular, the function of large, national institutes in the European innovation system will change and those institutes that are most adept at flexibly and speedily exploiting new R&D opportunities will take up a key position in the evolving European Research Arena. Unfortunately, just as is the case in terms of technological innovation, there are

no designs for institutional innovations, that are robust for a broad rather than narrow set of possible European transition scenarios. In other words, in terms of institutional innovation we also have to a look for a robust portfolio of institutional innovations. Again the adagio “think globally, act locally” is relevant here. National institutes must on the one hand become more globally aware, on the other hand more locally involved. This is particularly relevant for the Netherlands, which already serves as energy mainport for Europe. Contributing to European ambitions in this case could mean, that the present emphasis on participating in European research and development networks should not lead to diminished attention for global technological co-operation with non-European OECD nations or developing countries. Indeed, scenarios like SUSTAINABLE TRADE OR FENCELESS EUROPE put a premium on institutional alliances outside Europe. At the same time institutional alliances on the regional level are of equal importance in order to bridge the awkward gap between research and implementation more securely. Such global and local alliances are likely to involve much more than temporary co-operation in individual projects, but could involve the creation of spin-offs, not just with commercial intentions for specific innovations, but also to venture jointly into globally or locally specialised research and development trajectories.

Dutch innovation niches: Four exemplary visions

6 Dutch innovation niches: Four exemplary visions

6.1 From metaphorical to physical landscapes

Metaphorical landscapes and regional transitions

In the preceding part of this essay we have used the term landscape in a metaphorical sense as is common among transition-oriented social scientists when referring to geopolitical and socio-cultural characteristics at the macro level. The four European transition scenarios are derived from contrasting landscape developments on the global scale that circumscribe the constraints and opportunities facing European energy and environmental ambitions. These four scenarios contain possible plots facing the Netherlands as a game-changing player on the European scene. In this final chapter we will sketch four physical landscapes on the regional level that could potentially result from these metaphorical views on a global scale. These artist impressions of physical landscapes depict technological innovations compatible with each of four scenarios. Undoubtedly, the European energy transition scenarios described on the basis of failing hydro-carbon markets and/or climate change policies will impress some mainstream energy experts as unduly pessimistic. To redress this impression, the regional landscapes sketched below are intended as a diverse set of potentially happy endings on the regional scale.

Physical landscapes and the role of ECN

ECN is the central organisation for energy research and development in the Netherlands. In view of our emphasis on institutional innovation in addition to technological innovation, the artist impressions are accompanied by hypothetical scripts of the constructive role ECN might play in bringing about such landscapes. They illustrate how ECN could possibly play a role in shaping and implementing European energy ambitions by making use of strategic experimental niches in the Netherlands. The examples demonstrate the concrete results of choosing for specific positions in the energy value chain and choosing for specific types of institutional innovation. Clearly, the role of ECN in changing physical landscapes is not centre stage. As a research and development organisation ECN plays a supporting role as initiating and facilitating actor for the development of the suggested plots. It should be clear, that the artist impressions and hypothetical scripts sketch a totally imaginary and thoroughly incomplete picture of possible regional futures in the Netherlands. They are merely exemplary sketches of regional landscape changes ultimately driven by energy innovations.

6.2 FIREWALLED EUROPE – nuclear cogeneration on Texel

Nuclear dreams: the multipurpose High Temperature Reactor

The High Temperature Reactor (HTR) is an innovative design for generating nuclear energy in an inherently safe, small-scale and affordable way. With inherently safe we refer to the fact that core meltdowns are impossible because in the event of cooling failures natural convection processes take over and allow for sufficient cooling to prevent disasters. With small-scale we refer to the possibility of modular design at relatively low capacities of some tens of Megawatts. With affordable we refer to the fact, that the process design is relatively straightforward and allows modular fabrication for multiple purposes. The HTR is now one of the key innovative research themes of NRG and could well lead to rapid commercialisation when problems of fuel provision and waste storage are solved at the European level as is presumably the case in the FIREWALLED EUROPE scenario. Island communities are ideal environments for such multi-purpose generation units, because they match the autarchic tendencies of islanders while at the same time allowing a secure source of additional income.

ECN's role in bringing nuclear cogeneration to Texel

In the wake of a nuclear renaissance in the FIREWALLED EUROPE scenario pressures to rationalise European energy research and reintegrate nuclear and non-nuclear research enforce ECN to reconsider earlier intentions to separate the two. At the same time, on-going bilateral talks on fusion of Dutch and Belgium nuclear research institutes are enlarged and ultimately lead to the founding of a new European umbrella organisation, ECBEN, the Energy research Centre of the Benelux. The European Commission views ECBEN as a relatively independent partner and nuclear watchdog in community research programmes, because it is not directly linked to major national nuclear interests in France, Britain and Germany who are vigorously pursuing the implementation of large-scale third generation designs. ECBEN becomes the central organisation for European HTR research and receives long-term institutional funding from the Commission. The lead in HTR demonstration plants is however taken by South Africa and India, where desalination becomes the major purpose in view of the increasing scarcity and unreliability of rain-fed water sources in remote regions. With European starter funds, ECBEN creates a Belgium spin-off company that takes care of the appropriate licensing procedures at the European level and starts looking for launching customers for a European multipurpose demonstration plant. They are able to convince the mayor of Texel to hold a referendum on nuclear energy promising to keep dramatically increasing local prices for electricity and hydrogen stable for a period of 20 years. The referendum turns out to be an unqualified vote for nuclear.

6.3 FOSSIL TRADE - coal refineries on the third Maasvlakte

Coal dreams -A smart and clean carbochemical industry

The coal industry is generally viewed as dumb and dirty. There are no technological reasons why the coal industry cannot become smart and clean. In fact, the Netherlands was a premature European frontrunner in this field when constructing the coal gasification plant at Buggenum. It could regain its prominent position, when the prospects for coal-based manufacturing of chemical building blocks improve in a fossil fuel dominated world. The increasingly threatened role of Rotterdam in an Asian oriented global economy may ultimately lead to aggressive development of innovative industrial infrastructure. The third Maasvlakte is designed with three goals in mind: to strengthen the coastal barrier in view of increasing sea-level rises, to develop an industrial complex of coal gasification and liquefaction plants to regain Rotterdam's logistical role as the major energy and materials hub of Northwest Europe and to find an alternative location for an energy-intensive greenhouse sector, that is increasingly turning to the production of bio-engineered chemical specialties. The resulting green-field complex is a smart and clean follow-up of earlier attempts to integrate the waste heat and carbon cycles of the refinery and green-house sectors near Rotterdam.

ECN's role in bringing a smart and clean carbochemical industry to Rotterdam

The problems of integrating new process technologies based on advanced separation and catalytic technologies developed by ECN into existing petrochemical plants appear insurmountable. Instead of aiming for short-term improvement of industrial efficiency in existing industry, ECN changes its research strategy taking duly notice of two important global developments: the blossoming of new carbochemical plants in the USA and Asia and the progress of bio-engineered specialties in Singapore and Taiwan. Rather than concentrating vainly on improving the core processes of existing producers of bulk chemicals, ECN concentrates on niche markets combining the use of cheaply produced bulk chemicals from coal with expensive designer biochemicals. Curiosity driven experiments lead to several patents that could be of importance for the construction of easily recyclable carbon-based car parts. The patents are sold to a start-up company in which DSM, a bio-engineering service company from Singapore and a new conglomerate of greenhouse franchisers participate with equity capital. The demonstration plant for large-scale production of degradable biocarbons forms an integral part of the design for the third Maasvlakte.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6.4 SUSTAINABLE TRADE – biomass production in the Zijpe estuary

Biomass dreams – from seed-potatoes to salt-water plant seeds

The rise of biomass trade to limit greenhouse house gas emissions will reverse the trend of CO2-concentration in the atmosphere. Nevertheless, sea levels will continue to rise for decades. In response, The Netherlands may turn to natural processes of land accretion instead of artificial containment with dikes and waterworks. In this framework, the Hondsbossche Zeewering, a large defensive structure built to protect a vulnerable former estuary, may be demolished in part allowing the sea to regain territory. Land is built up slowly before and behind the old sea dike. At the same time, the Netherlands is increasingly turning to imported biomass as feedstock for energy and materials. While originally intended as a nature reserve, the Zijpe estuary suffers from massive blooms of salt-water plants as a result of nutrient run-off from nearby bulb growers. It is decided to harvest the plants for local energy generation, but this is only the first step in a chain of events, finally leading to the establishment of several agro-industrial enterprises devoted to the production of high value-added, bio-engineered salt-water plants for seed export purposes to delta areas around the world. The new strains allow the clean production of biofuels while at the same time maximising silt capture by modified root and stem structures.

ECN's role in bringing adaptive biofuels to developing countries

In the SUSTAINABLE TRADE scenario Europe succeeds in directing an orchestra of treaties in the area of climate change successfully. However, intensified energy research and development in co-operation with development countries is part of the deal. In the aftermath of implementing the new Beijing Protocol, the European Community establishes several pan-European energy and environmental research organisations with large-scale institutional co-funding. Strongly supported by strategic alliances with several European universities ECN takes the lead in forming the Eurodelta organisation specialising in energy and environmental technologies for large and densely populated delta regions. The emphasis on sustainable trade coupled with the wish to improve the adaptive capacity of poor delta dwellers, leads to intensive international co-operation in the areas of wind pumps and local biofuels. It appears that some salt water plants are amenable for use as biofuel feedstock. Eurodelta becomes involved in the harvesting of salt water plants in the Zijpe estuary and establishes a pilot plant for conversion. Local alliances with farmers ultimately lead to the establishment of new companies specialising in the development of multipurpose salt water feedstocks that can be used for biofuel production while at the same time consolidating soils, thus functioning as combined climate change mitigation and adaptation technology.


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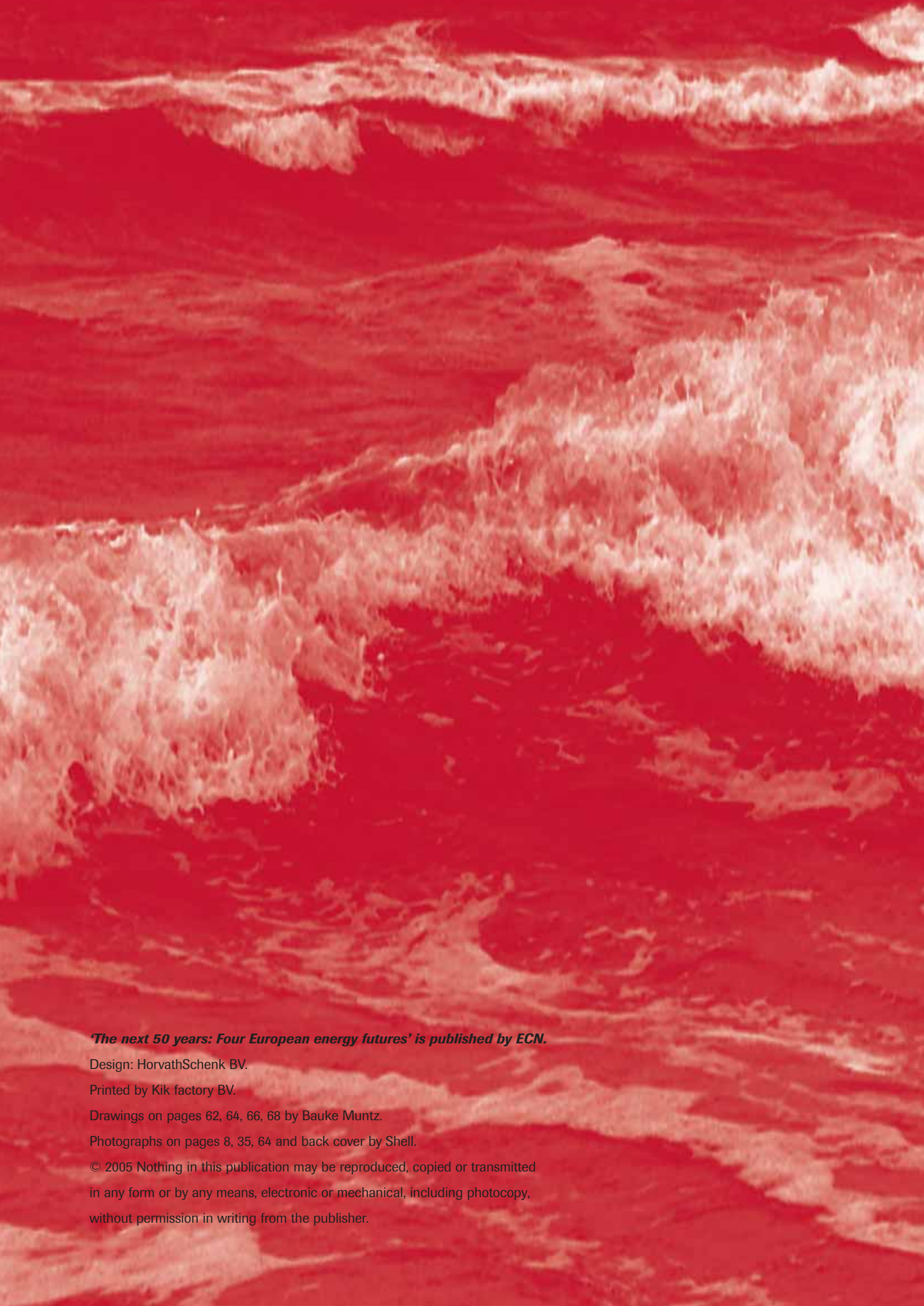
6.5 FENCELESS EUROPE – Amsterdam as hydrogen gateway

Hydrogen dreams – fuel cell cars solve traffic jams and local air pollution

The future of hydrogen is often viewed as a chicken-and-egg problem in the sense that without adequate infrastructure large-scale investments are unlikely to come forward. Moreover, the dominant players of today have few incentives to cannibalise their own business by prematurely supporting alternative infrastructural leaps towards hydrogen in which the value-added chain is thoroughly changed. However, rather than transitions in energy infrastructure, transitions in transportation infrastructure may provide the key to a regional hydrogen economy. In an increasingly crowded world driven by demanding, experiment-prone and environment-conscious consumers-citizens new solutions to mobility problems gain priority. In the FENCELESS EUROPE scenario fuel cell cars based on hydrogen from fossil fuels with carbon capture and storage can compete with traditional road systems when they offer substantial, additional advantages. Such advantages could be based on providing fast individual access to city centres through use of the existing infrastructure for railways. Electronically controlled cars and busses would use the revamped roadbeds and inner city yards for fast access and easy parking. Long-term leases of hydrogen sales and parking spaces would provide attractive returns for venture capitalists taking over the national railway company NS. The city of Amsterdam would support such plans by banning private vehicles in the inner city in order to radically solve problems of parking congestion and local pollution, while a dense network of hydrogen busses and trucks improve inner city accessibility and attractiveness. The Amsterdam experiment could have revolutionary consequences for urban regeneration efforts all over Europe.

ECN's role in supporting regional hydrogen systems

ECN has a long history of involvement in hydrogen-related research with decidedly mixed results. Its role in the emergence of hydrogen driven fuel cell cars in Amsterdam is two-fold. On the hydrogen supply side it played a crucial role in developing efficient, small-scale CO2 capture technologies in co-operation with Energy Valley, a private-public energy umbrella organisation for the Dutch northern provinces with strong backing of Gasunie. On the hydrogen demand side, international co-operation with fuel cell developers in China led to Chinese mass-production of advanced fuel cell carriages, based on individually driven wheels and advanced electronic controls. While the carriages are mass-produced and continentally shipped, the remainder of the car is customer-designed and assembled on site in order to cater to widely different lifestyles and transportation exigencies. The Amsterdam venture is based on local hydrogen production from natural gas and local design, manufacturing and assembling of fuel cell cars taking account of evolving customer lifestyles.



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ECN
Westerduinweg 3
P.O. Box 1
1755 ZG Petten
The Netherlands
tel. +31 224 564949
fax +31 224 564480
corp@ecn.nl

www.ecn.nl