ISSN 2052-1618

'Low Carbon' Scenarios, Roadmaps, Transitions and Pathways: an Overview and Discussion

Prof. Tim Dixon

Oxford Institute for Sustainable Development, Oxford Brookes University

Retrofit 2050 Working Paper

October 2011

WP2011/6

WP2011/6

‘Low Carbon’ Scenarios, Roadmaps, Transitions and Pathways: An Overview and Discussion

Tim Dixon

Abstract

There are a range of studies based in the low carbon arena which use various ‘futures’-based techniques as ways of exploring uncertainties. These techniques range from ‘scenarios’ and ‘roadmaps’ through to ‘transitions’ and ‘pathways’ as well as ‘vision’-based techniques. The overall aim of the paper is therefore to compare and contrast these techniques to develop a simple working typology with the further objective of identifying the implications of this analysis for RETROFIT 2050. Using recent examples of city-based and energy-based studies throughout, the paper compares and contrasts these techniques and finds that the distinctions between them have often been blurred in the field of low carbon. Visions, for example, have been used in both transition theory and futures/Foresight methods, and scenarios have also been used in transition-based studies as well as futures/Foresight studies. Moreover, Foresight techniques which capture expert knowledge and map existing knowledge to develop a set of scenarios and roadmaps which can inform the development of transitions and pathways can not only help potentially overcome any ‘disconnections’ that may exist between the social and the technical lenses in which such future trajectories are mapped, but also promote a strong ‘co-evolutionary’ content.

1.0 Background and context

In recent years a large number of futures-based studies have been developed in the field of low carbon technologies. For example, McDowall and Eames (2006) identified six distinct though overlapping types of futures studies in the field of hydrogen. These are shown in Table 1 and are categorised according to whether they are 'descriptive' or 'normative'.

Table 1 A typology of hydrogen futures (source: McDowall and Eames, 2006)

Descriptive	**Forecasts** use formal quantitative extrapolation and modelling to predict likely futures from current trends.
	Exploratory scenarios explore possible futures. They emphasise drivers, and do not specify a predetermined desirable end state towards which must storylines progress.
	Technical scenarios explore possible future technological systems based on hydrogen. They emphasise the technical feasibility and implications of different options, rather than explore how different futures might unfold.
Normative	**Visions** are elaborations of a desirable and (more or less) plausible future. They emphasise the benefits of hydrogen rather than the pathways through which a hydrogen future might be achieved.
	Backcasts and pathways start with a predetermined 'end' point—a desirable and plausible future. They then investigate possible pathways to that point.
	Roadmaps describe a sequence of measures designed to bring about a desirable future. Studies from the previous four groups, or elements of these groups, frequently form the basis for the identification of specific measures, but not always.

These categories of 'futures studies' can also usefully be set within the context of 'foresight'. For Loveridge (2009) 'foresight' divides neatly (as per the OED definition) into: (i) 'soft' (the action of looking forward and caring for, or provision, for the future); and (ii) 'hard' (the muzzle sight of a gun) connotations. Loveridge (2001: 781) also separates 'real foresight' from 'institutional Foresight', with the former characterised by individual or small group activity of anticipation, as distinct from policy and planning-led Foresight. However, in a more general sense Miles and Keenan (2002:15) suggest that the term foresight is understood to describe:

'a range of approaches to improving decision making…Foresight involves bringing together key agents of change and sources of knowledge in order to develop strategic visions and anticipatory intelligence. Of equal importance, foresight is often explicitly intended to establish networks of knowledgeable agents'.

Indeed, for Saritas and Aylen (2010) there is also an inherent commonality between foresight and roadmapping techniques, as both are highly participatory and interactive and both are policy and action oriented which suits a management context (see also Saritas and

Oner, 2004). Foresight thinking should also be guided by the use of a systemic framework for designing relevant methodologies which can be characterised by the use of five mental acts (Saritas, 2006).

Table 2 Five mental acts of Foresight (Saritas, 2006).

1. Systemic understanding	Aims to gain a shared understanding and mutual appreciation of topics and influencing factors as systems in their own contexts by scanning.
2. Systems analysis and modelling	Input from scanning is synthesised into conceptual models of situations in the real world.
3. Systemic analysis and selection	Analysis of alternative models of the future and prioritisation to agree a model of the future.
4. System transformation	Establishes the relationship between the future and the present to initiate a change programme.
5. Systemic action	Concerns the creation of plans to inform present day decisions for immediate change to provide structural and behavioural transformations.

As McDowall and Eames (2006) suggest, ‘forecasts’ are characterised by the use of quantitative methods to predict future trends based on current trends or surveys of expert opinion. Within foresight and futures studies forecasts as a standalone technique are of limited value over longer time horizons because of their inherent deterministic view of the future and of technological change; on their own, therefore, such techniques fail to acknowledge changing technological ‘regimes’ or ‘paradigms’, or disruptive impacts. Many therefore agree that other techniques offer therefore greater opportunity and flexibility to explore a range of possible outcomes.

In this paper four of the techniques outlined in McDowall and Eames (2006) are explored in more detail. These are: scenarios; roadmaps; transitions and pathways, but the concept of ‘visions’ is also examined in more detail. The focus of the paper is ‘low carbon’ and each of these techniques is now examined in turn with examples of each provided from the context of two fields of study which are important elements of RETROFIT 2050: (i) energy; and (ii) cities and the built environment. The overall aim of the paper is therefore to compare and contrast these techniques to develop a simple working typology of techniques with the further objective of identifying the implications of this analysis for RETROFIT 2050.

2.0 Scenarios

For Hughes (2009) scenario thinking is the:

'use of the imagination to consider possible alternative future situations, as they may evolve from the present, with a view to improving immediate and near term decision-making'.

This involves three key objectives which are improving protective decision-making; improving proactive decision making and consensus building.

The UK Government Office of Science (2008) suggests that scenarios are a tool for thinking about possible different futures which can be used to inform policy making. In this way uncertainties can be rehearsed and explored in order to highlight key issues or potential options for further detailed investigation. Scenarios can therefore be used as an analytical tool to broaden and deepen the way in which organisations see their external environment and how they might respond, or to help define future vision and strategic priorities. They can also be used for rehearsing different policy options to highlight strengths and weaknesses and to future proof decisions or investments. Scenarios are not predictions of the future therefore but to be successful they should (Strategy Unit, 2004):

- Be based on analysis of change drivers;
- Allow critical uncertainties and predetermined elements to be distinguished;
- Be compelling and credible; and,
- Be internally logical and consistent.

Moreover scenarios cannot in themselves make decisions; begin an unstoppable course of action; be entirely correct or indeed offer totally persuasive arguments for everyone. As Saritas and Aylen (2010:1064) suggest scenarios can be thought of as *'stories about the future'*, or narratives created by researchers or participants in a workshop[1].

McDowall and Eames (2006) differentiate 'exploratory scenarios' from 'technical scenarios'. Exploratory scenarios seek to inform policy making by illuminating drivers for change often drawing on tacit knowledge and expertise in order to construct internally consistent storylines which outline a number of possible futures. These tend to be long term in nature and can include trend-breaking developments. In contrast, technical scenarios are more specific about the way in which systems are envisaged in the future and how particular technologies underpin them. Frequently they have tended to be 'static' studies which often overlook the social and cultural dimensions of technological change.

Saritas and Aylen (2010) provide a useful typology of scenarios:

- Profile scenarios (usually developed around a matrix) with the cross-fertilisation of tow key issues or drivers for change.
- Archetypes or Alpha, beta and delta scenarios where alpha represents a 'business as usual' future; beta that some things can go wrong and delta that changes in direction will occur.
- Success scenario, or one single normative scenario.

In the context of UK Government Foresight techniques, scenarios have been based on a 'deductive' process, using techniques developed by SRI (formerly the Stanford Research Institute) in the USA (UK Government Office of Science (2008)). This helps create a '2x2' scenarios matrix (or what Saritas and Aylen (2010) suggest is a 'profile' scenario) which captures four possible futures by exploring critical uncertainties. Essentially the scenarios are deduced from an analysis of the drivers for change which are important and uncertain,

[1] Or indeed developed from existing scenarios (see Strategy Unit, 2004).

and these are prioritised to identify the two most important uncertainties which create the scenario 'axes'. This then helps create scenarios through an exploration of the outcomes when uncertainties at each end of the x and y axes are combined. Critics have argued that such a matrix produces at least one scenario which is too 'good to be true' and one which is 'to be avoided', but a counter argument is that the scenarios produced represent, if they are well constructed, and have orthogonal axes (i.e. distinct uncertainties which do not collapse into each other) (UK Government Office of Science (2008), a range of plausible outcomes for the future.

In contrast, 'inductive scenarios' are developed through interpretation of data, trends and other material by a core or expert group. Explorative techniques also encourage multiple scenarios (focused on 'what next?' or 'what if?' questions), whereas a 'normative' approach to scenario-building encourages a 'preferred' vision of the future and outlines different 'pathways' (see below) from the goal to the present (i.e. they involve 'backcasting' typically starting with the most desirable future and concern questions such as 'where to?' and 'how to?' (Saritas and Aylen, 2010)).

The deductive approach to scenarios offers a number of benefits which include a structured nature, with a clear relationship between drivers and scenarios, and a relatively simple way to link the scenarios with strategic and policy implications ((UK Government Office of Science (2008)).

Hughes et al (2009) raise some fundamental issues over the use of scenario-based techniques for exploring low carbon futures based on a review of 21 UK and international low carbon studies. Indeed Hughes (2009) provides an alternative typology for futures based low carbon studies. These include:

- High level trend studies, which produce contrasting future scenarios on the basis of the increased prominence of one or more societal trends.
- Technical feasibility studies, which aim to focus in detail on the technical make-up of an energy system or sub-sector and explore how a combination of energy technologies can deliver supplies often within an external carbon constraint.
- Modelling studies, which incorporate many of the elements of technical feasibility studies, but with increased quantitative content.

For Hughes (2009) and Hughes et al (2009) such techniques, whilst advancing the cause of energy futures as a long term planning issue have failed to address key issues. In particular the need to consider future technologies in detail opens up uncertainties as decarbonisation itself acts as a driver for substantial technological change. Societal change and interaction with technology is also complex in this arena and there are also a wide variety of actors which need to be engaged. Critically, Hughes et al argue that many scenarios studies in this field lack strategic applicability for three main reasons:

- Focus on normative, exogenous constraint such as a carbon emissions reduction target.
- Reliance on high level trends which can lead to overly polarised and homogenised scenarios.
- Co-evolutionary content, or a recognition that technology interacts with social, cultural and political systems is often weak, and fails to identify actors and the key networks which underpin socio-technical change.

Nonetheless there have been some helpful recent examples of high level trend studies in the fields of energy and cities and the built environment. Some of these are now examined in detail.

2.1 Examples of Scenarios

2.1.1 National level: Foresight: Powering Our Lives

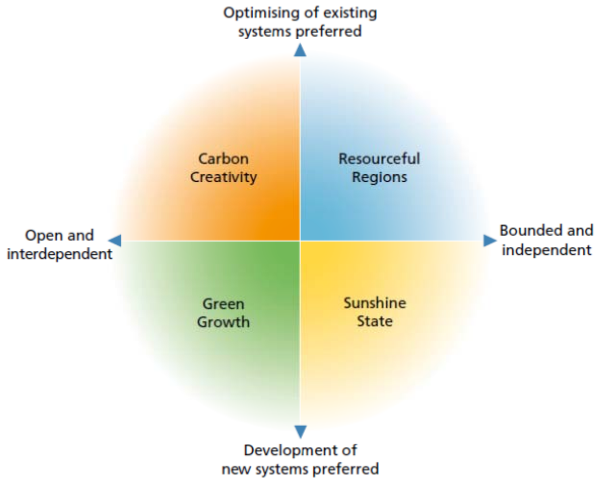
The scenarios work for this programme, which was completed in 2008, followed a six stage process (Government Office of Science, 2008):

1. Scoping question defined. This aimed to explore how the built environment can evolve to help manage the transition over the next five decades to secure, sustainable, low carbon energy systems that meet the needs of society, the requirements of the economy and the expectation of individuals.
2. An initial set of drivers of future change was identified. These comprised:
    - Climate change and the environment.
    - Demographic change.
    - Infrastructure.
    - Technology and materials.
    - Public attitudes.
    - The economy (market forces).
    - The political framework.
3. Initial options for scenarios were developed and reviewed on the basis of identifying two axes of uncertainty. These comprised an ‘x axis’ which describes significant uncertainties in the global political and economic context in 2050, ranging from ‘open and interdependent’ relationships, where collaboration and partnership is the norm to ‘bounded but not independent’ relationships characterised by bi-lateral rather than multi-lateral relationships. The ‘y axis’ examined the type of innovation which attracts investment, ranging from the fostering of new systems or emerging technologies and novel systems at one end of the axis to an emphasis on optimising existing systems whether in energy, buildings or the built environment. In the face of energy shortages, for example, governments may well decide to make incremental changes to infrastructure and so place systems under less stress. These differences, however, are focused on ‘scale’ rather than exclusive choices between technologies; for example renewable may be found under ‘existing systems’ as well as at the other end of the axis.
4. From this analysis four scenarios were developed. These are shown in Table 3 and illustrated in Figure 1. These scenarios are strongly framed within a ‘co-evolutionary’ approach which recognises that technological innovation needs socio-economic viability and appropriate governance systems to be successful (Rydin et al, 2010).
5. In parallel with the development of the scenarios technology ‘roadmapping’ was carried out to help underpin the scenarios by capturing key technologies and the enablers and constraints to deployment and takeup.
6. Finally the scenarios were tested using ‘wind tunnelling’ whereby policy and strategic decisions are tested against the scenarios to see which are robust against a range of future options and which are not.

Table 3 Scenarios – Foresight: 'Powering Our Lives' (Government Office of Science, 2008)

Scenario	**Characteristics**
'Resourceful Regions'	This is a world in which political trust has diminished on a world scale, although bilateral trade continues. Most UK energy comes from fossil fuels with innovation being focused on the optimisation of existing systems. These are used more efficiently than in the past, but the focus is more on energy security and the cost of fuel. English sub-regions have a high degree of autonomy, matching Scotland and Wales. In situations of resource scarcity, regional trade in fuel carries considerable leverage. Some regions do deals with overseas countries on energy supplies. Nuclear power still plays a role but many regions have also invested in appropriate renewable technologies. In the built environment, retrofitting rather than new build is the preferred approach. New buildings are increasingly built in a local vernacular style, and there is urban green space to tackle overheating. Living conditions vary widely as regions have their own economic structures and differing levels of economic success. Most regional governments support public transport.
'Sunshine State'	International solidarity has fallen by the wayside in response to climate change and expensive energy. There is an emphasis on localism to respond to energy problems. Energy efficiency measures are universal. Retrofitting is sometimes done alongside adaptation work to help buildings cope with warmer and wetter conditions. Green roofs and parks are common to counter flooding. New build commonly uses offsite construction methods, often from overseas. People are active energy users and know about the energy use of everything they own. Many belong to local 'time banks' (where people use their time, rather than currency, as a form of transaction) or use local currencies. Innovation has led not only to the introduction of novel technologies but also new organisations, ideas and approaches. There has been considerable expansion of renewables including solar energy and biomass.
'Green Growth'	In this world, fossil fuel depletion and climate change are serious concerns. Novel technologies and systems are regarded as the way to deal with them. Social values emphasise universalism and benevolence. There is an emphasis on decoupling economic growth from carbon emissions and a substantial carbon tax to drive change. By 2050 the building industry reflects these developments and there are now many highly energy-efficient new houses and other buildings and less emphasis on retrofitting old property. People take responsibility for their energy use. Most energy comes from renewable sources including big projects such as the Severn Barrage, offshore wind farms, and solar energy farms in Africa. There is some local renewable energy, including energy-from-waste schemes, partly to offset the inherent instability of electricity supplies transmitted across thousands of kilometres.
'Carbon Creativity'	Decarbonisation is a major theme in this world, prompted by a carbon market in which all goods and services carry a carbon price. There has been considerable investment in Carbon Capture and Storage. Renewables are small in scale and volume and little renewable power is connected to the grid. There has been a boom in carbon consultancy, in which there are EU-recognised qualifications and London is the centre of world carbon trading. Europe also plays a major role in regulating energy markets. Energy costs and regulation have driven substantial retrofitting and renewal of the existing built stock, both domestic and commercial. High density, mixed-use developments are popular because of their community feel as well as their energy efficiency and proximity to transport nodes. They feature optimisation of existing technology for capturing energy, especially from solar power and for using it effectively, for example advanced glazing.

Figure 1 Foresight 'Powering Our Lives' scenarios (Government Office of Science, 2008)

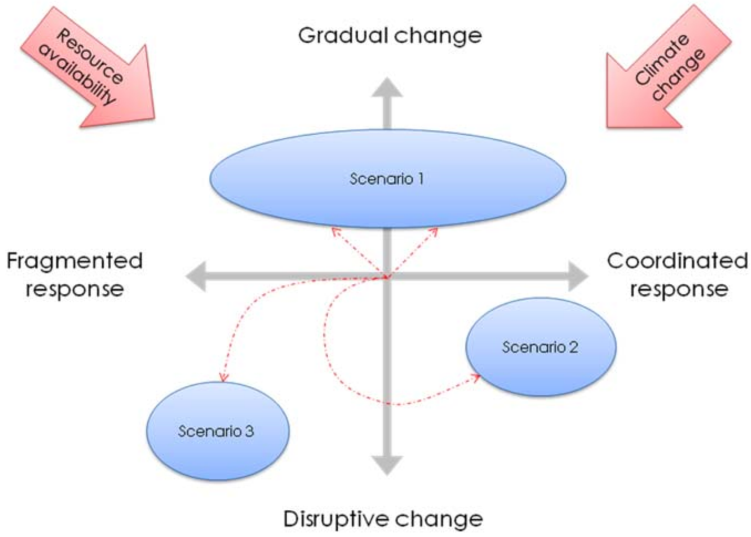


2.1.2 City Level: Oxford University Future of Cities

The Oxford University (Martin School) Future of Cities (FoC) programme aims to explore a range of influences on how cities will develop over the next 50 years and the implications for decisions in boardrooms, communities, and city and national governments. The programme of research is underpinned by the development of three scenarios applicable at global and city level.

The scenarios are based on an inductive approach which developed a 2x2 matrix based on two axes. The y axis represents the pace and nature of environmental change on a continuum from gradual to disruptive change. Environmental change includes the extent and impact of global climate change, natural resource shortages and ecosystem degradation and collapse as well as uncertainties relating to the timing and impact of change on cities and their ability to adapt and be resilient. In contrast the x axis represents the extent of social co-ordination and social cohesion in the context of city development. This is represented by uncertainties regarding global competition, coordination and collaboration, social divides links between poverty and security and the nature of conflict. The axis runs as a continuum from 'fragmented' to 'co-ordinated'. This is shown in Figure 2 and further details are provided in Table 4.

Figure 2 'Future of Cities' Scenarios (source: http://news.noahraford.com/?p=558)



As a result of interviews and other analytical work three scenarios were developed which were envisaged as evolving notionally over time. For example, Scenario 1 unfolds into a hybrid world of gradual change and mixed response, Scenario 2 veers towards a fragmented response until it experiences disruptive change then swings back towards co-ordination.

The key drivers for change identified in the programme were exogenous factors and considered to be beyond the control of cities. These included:

- International capital/investment
- State responsiveness
- Technology/ICT
- Mass migration
- Localisation
- Socio-technical lock-in/inability to change
- Resource shortages
- Conflict and crime
- Institutional innovation
- Environmental change/climate.

Table 4 'Future of Cities' Scenarios (INSIS, 2009 and http://news.noahraford.com/?p=558)

Scenario	
'Gulliver's World'	This world comprises a grouping of highly interconnected and economically interdependent nations (the 'bloc') managing steady, albeit slower, economic growth, a variety of more loosely coupled cities and nations (the 'fringe'), and more isolated failing and failed cities (the 'pockets').
'Transformation…or Bust'	A world where climate change and peak oil severely strain cities across the globe, but produce a revolution in more holistic values led by a generation of young leaders championing a new work-life-ecology balance. The world is shaken by a series of systemic failures and social upheavals as the global financial crisis – which cascaded into national recessions and sustained global depression – is followed by an uneven recovery. This uneven recovery further exposes the growing global gaps and divides in opportunities and burdens associated with rampant economic globalisation. This leads to the widespread conclusion: the political-economy ideology underpinning the rise of capitalism, global economic growth and the design of international and multilateral institutions in the latter part of the 20th century is both morally corrupt and unsustainable.
'Triumph of the Triads'	A world where global systemic risks exceed our capacity to manage them, producing state failure, economic stagnation and predatory warlordism. Rigid, underfunded, understaffed, and, in most cases, underwater or food- and water-insecure, many central governments are unable to cope with the burden of change and cities become increasingly autonomous. Staggering towards disaffection, centralised local authorities and administrations collapse after wave upon wave of community-based, ideologically-driven non-state actors outcompete, outfight, and outbid them for control.

2.1.3 City Level: University of Manchester- PLUREL

The University of Manchester's PLUREL project applies four different scenario storylines to explore possible futures for Europe's urban and peri-urban areas. These scenarios were based on the SRES (Special Report on Emissions Scenarios) global scenarios of the IPCC and adapted to the PLUREL agenda by (PLUREL, 2008):

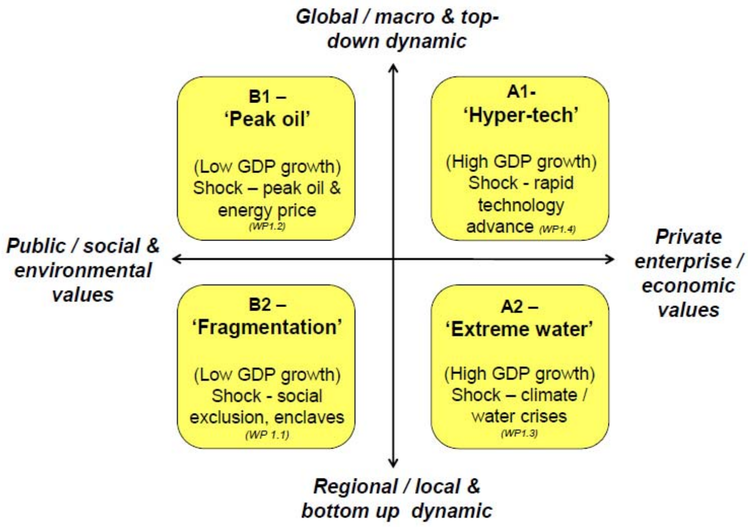
- Applying the global scenarios to the EU to 2025 and 2050.
- Developing a series of possible and plausible shocks (i.e. rapid and important changes in particular sectors or themes).
- Focusing on the implications of each scenario for urbanisation and peri-urban land use change.

This resulted in a 2x2 matrix (Figure 3) with codes derived from the IPCC scheme. Here the x axis focuses on the continuum between public and collective values through to private enterprise values, whilst the y axis represents globalised top down dynamic through to localised, bottom up approaches. Table 5 summarises the scenarios.

Table 5 PLUREL scenarios (source: CURE, 2007)

Scenario	
A1 High Growth ('Hyper-Tech')	This describes a future world of rapid economic growth, global population that peaks in midcentury, and the rapid spread of more efficient technologies. For peri-urban areas in Europe, this scenario is likely to see small 'polycentric' towns and cities become even more popular. New transport technologies lead to more rapid journeys and the expansion of the commuting distances around towns and cities. This leads to peri-urbanisation and 'metropolitanisation' of rural areas on a massive scale.
A2 Self Reliance ('Extreme Water')	This describes a more heterogeneous world of self reliance and preservation of local identities. Peri-urban areas are strongly affected; affluent yet vulnerable city-regions such as London or the Dutch Randstad spend huge sums of money on defence and adaptation strategies. Population growth due to climate-induced migration puts more pressure on urban infrastructure and services.
B1 Sustainability? ('Peak Oil')	This describes a future of environmental and social consciousness – a global approach to sustainable development, involving governments, businesses, media and households. For periurban areas, high energy prices have an enormous effect on location choices as transport costs limit commuting distances. Although tele-working is encouraged, most people attempt to return to larger cities and towns, and more remote rural areas decline.
B2 Fragmentation ('Walls and Enclaves')	Europe sees a fragmentation of society, in terms of age, ethnicity and international distrust. The ethnic division of cities is driven by the increased in-migration of the working-age population from outside and within the EU. Cities become more dispersed as younger migrants dominate city centres and older natives populate the outskirts and enclaves outside the cities, so that peri-urban areas become 'peri-society' areas.

Figure 3 PLUREL scenarios (source: CURE, 2007)



2.1.4 EPRSC Urban Futures: University of Birmingham

The Urban Futures project which is a four year programme running from 2008 aims to develop a set of future scenarios which will provide the backdrop against which the impact of 'sustainable' urban regeneration can be measured at city level focusing on Birmingham, Lancaster and Worcester (Urban Futures, 2008). The project examines eight dimensions of sustainability (ranging from biodiversity through to social needs, aspirations and planning policy). Based on a literature review the research focuses on four scenarios based closely on the work of Gallopin et al (1997) of the Global Scenarios Group (GSG) who suggested three world types of change (Table 6):

- 'Conventional worlds', which envisions the global system of the 21st century evolving without major surprises or shocks, and with a future shaped by the continued evolution and expansion of current societal values. Within these two variants comprise 'policy reform', which strengthens and underpins policy change to achieve a sustainable future, and 'reference' linked with mid-range assumptions on population and technology change.
- 'Barbarisation' scenarios envisage deteriorating socio-economic conditions with a 'breakdown' variant leading to catastrophic conflict, economic collapse and disintegration of society and 'fortress world' which features an authoritarian response to breakdown.
- 'Great Transitions' explore visionary solutions to the sustainability challenge and create new socio-economic arrangements and changes in value systems. An 'eco-communalism' variant sees a green vision of bio-regionalism and localism with small technology solutions and the 'sustainability paradigm' sees less wholesale change with less localism and a focus on change rather than replacement.

Essentially the work of Global Scenario Group is based on a hierarchical or tiered approach to scenarios.

Table 6 EPSRC ‘Urban Futures’ Scenarios

Scenario	
‘Market Forces’	Well-functioning markets are the key to resolving social, economic and environmental problems. It assumes the global system in the 21st century evolves without major surprise and incremental market adjustments are able to cope with social, economic and environmental problems as they arise.
‘Policy Reform’	There is belief that markets require strong policy guidance to address inherent tendencies toward economic crisis, social conflict and environmental degradation. The tension between continuity of dominant values and greater equity for addressing key sustainability goals will not be easily reconciled.
‘New Sustainability’	New social-economic arrangements and fundamental changes in values result in changes to the character of urban industrial civilization, rather than its replacement.
‘Fortress World’	The world is divided, with the elite in interconnected, protected enclaves and an impoverished majority outside. Armed forces impose order, protect the environment and prevent a collapse.

2.1.5 Other perspectives

There have also been several other examples form the world of real estate which have focused strongly on sustainability, although these have adopted shorter time frames than 2050 and have focused primarily on investment and development decisions at project or building level although within a wider city, national and global context. The main characteristics of these are identified in Table 7.

Table 7 Examples of other scenarios

Study	Drivers	Uncertainties: x and y Axes	Scenarios
Real Estate Investment Management 2020 and Beyond (Outsights/Thomson Reuters 2009)	Ageing and demographic change Mobility and urban trends Cost of travel and new technology	Y axis: Globalisation and localisation X axis: unpredictable and predictability of behaviour, social political and economic structures.	'Corporate World' 'Global Utopia Survivors' 'Return to Merry Albion'
Built Environment Foresight 2030 (O'Brien et al, 2009)	Impact of globalisation/internationalisation of markets Sustainability issues Movement towards CSR Economic growth Climate Change Population growth Scarcity of natural resources/energy conservation Integration/social cohesion Search for improved quality of life Advance of ICT Changing nature of work Rising demand for mixed use development	Y axis: European integration X axis: Moves towards sustainability	'Bastions' 'Web' 'Zion'

3.0 Roadmaps

The roadmaps used in futures studies essentially replicate the characteristics of a spatial roadmap which is designed to set out paths or routes in a geographical space (Saritas and Aylen, 2010). As a metaphor roadmapping has therefore been used frequently in technology management, strategic decision-making and action planning since the early introduction of the technique by Motorola in the 1970s (Phaal and Probert, 2009). Galvin (2008), CEO of Motorola, suggests that a roadmap is:

'An extended look at the future of a chosen field of inquiry composed from the collective knowledge and imagination of the brightest drivers of change in that field'.

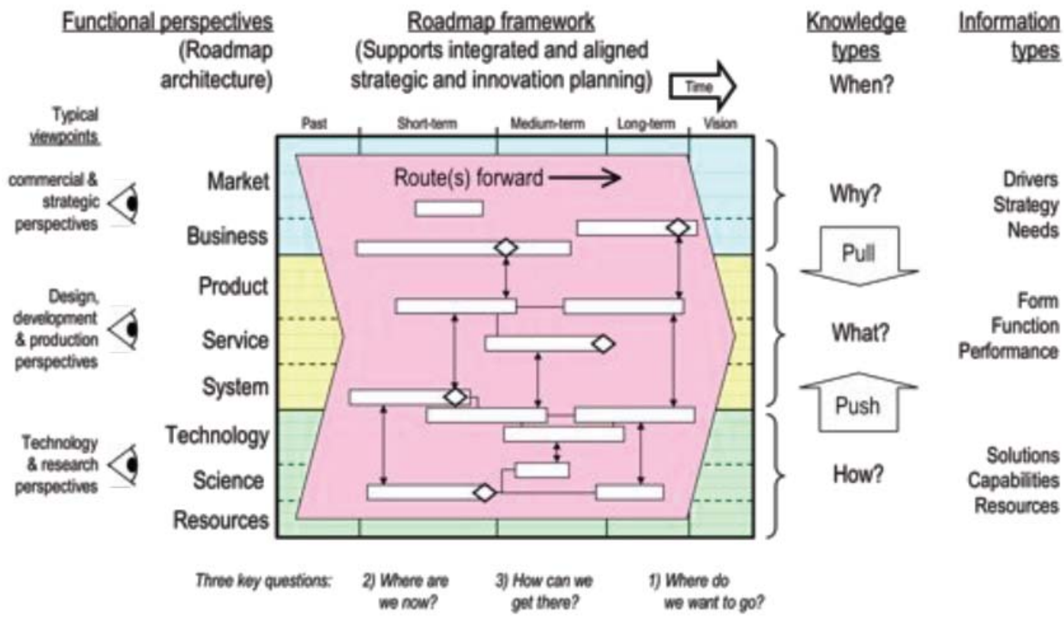
This suggests that knowledge and expertise are important and that roadmapping is forward-looking and flexible. For Saritas and Aylen (2010) the technique of roadmapping is useful for:

- Portraying structural relationships between science technology and applications.
- Improving co-ordination of activities and resources in uncertain and complex environments.
- Identifying, evaluating and selecting strategic alternatives to achieve desired science and technology objectives.
- Communicating visions to attract resources.
- Stimulating investigations.

- Monitoring Progress.

In recent years roadmapping has also been an important feature of UK government Foresight exercises (Government Office of Science, 2008). There is also a huge diversity of roadmaps; Phaal (2008) for example identified 1300 public domain roadmaps clustered in 18 groups. Roadmaps require the identification of nodes and linkages and can be represented visually by multiple layers; bars; network diagrams; and flow charts (Saritas and Aylen, 2010). A typical graphical representation is shown in Figure 4.

Figure 4 Schematic multi-layered roadmap, aligning multiple perspectives (Phaal and Probert, 2009)



This represents a focus on both demand and supply and market pull and technology push to be represented and helps address key questions such as:

1. Where do we want to go? Where are we now? How can we get there?
2. Why do we need to act? What should we do? How should we do it? By when?

Thus for Phaal and Probert (2009:2) roadmaps are:

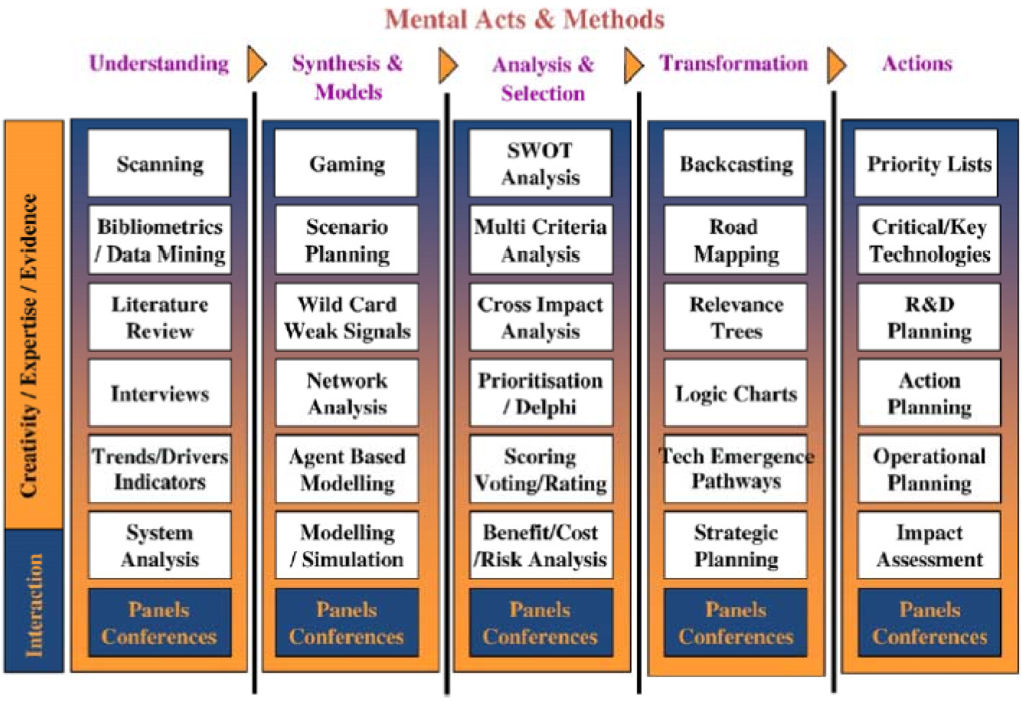
'simple, adaptable 'strategic lenses' through which the evolution of complex systems can be viewed, supporting dialogue and communication.'

However, there are certain shortcomings of roadmaps. They are (Saritas and Aylen, 2010) (see also Table 6):

- Normative rather than exploratory.
- Encourage linear and isolated thinking although stakeholder involvement can help overcome this.
- Difficult to disseminate because the output may be overly technical.

Both roadmaps and scenarios are valuable techniques to use in Foresight studies. In particular roadmaps can generate options and alternatives as to how to reach the most desirable state in the future, so that they guide decisions (Saritas and Aylen, 2010) (Figure 5).

Figure 5 The place and function of scenarios and roadmapping in overall Foresight methodology (Saritas and Aylen, 2010)



Roadmapping is particularly useful in the transformation phase linking the future with the present. Table 8 compares the advantages and disadvantages of roadmaps and scenarios.

Table 8 Comparison of scenarios and roadmaps—advantages (A) and disadvantages (D) (Saritas and Aylen, 2010)

Scenarios	Roadmaps
A: Exploratory and Normative — can both serve to explore alternative trajectories of the future and to describe the most desirable future A: Allow open and creative thinking A: Highly participative and interactive	D: Normative — more target oriented, therefore, focuses merely on the desirable future D: Suggest linear and isolated thinking D: More difficult to communicate with non-participants of the process as results too technical
D: Frequently used to describe one or a set of future circumstance(s). Do not necessarily give a pathway into the future. Therefore may not fulfil the expectations of Foresight, which is an action-oriented activity, alone D: Take longer to grasp particularly when presented in textual format D: More open ended and may lead to multiple interpretations	A: Connect the future with the present and inform long, medium and short term policies and actions A: Provide high information content in one single figure A: More precise and clear in terms of actions and how they lead to the development of technologies, products and markets

Roadmaps therefore useful tools in their own right but gain more power by being linked with scenarios. In this way roadmaps can become more exploratory by considering a set of probable futures. Scenarios therefore constitute the body of the roadmap, and can be used before, during, and after the roadmapping exercise has taken place.

In terms of practical examples McDowall and Eames (2006) suggest that in the field of hydrogen futures roadmaps studies have usefully identified barriers and what is needed to overcome them; that they often fulfil an advocacy function; and that stakeholder engagement is deployed.

There have been several examples of 'roadmaps' in the field of low carbon (apart from the Foresight example already discussed under scenarios) which are now discussed.

3.1 Examples of roadmaps

3.1.1 Arup Research Roadmap

Arup (2010: 3) define roadmapping as:

'a type of management forecasting tool that can be used in a number of ways-as a method for capturing a time sequence of trends, targets and responses, as a living agenda covering tactical and strategic level objectives as well as a company wide project plan. It can also act as an enabler for sharing market goals in supply chains and promotes team buy-in to corporate strategy and planning'.

Arup have therefore developed a strategic research plan which is used to develop and articulate a corporate research strategy, but the technique is also used as a business service advice to underpin clients. In the research roadmap Arup identify drivers (including for example, regulation, supply and demand for the energy sector) and also research elements both of which are scoped out over three time periods to 2050 (short-term; mid-term and long-term).

3.1.2 Roadmap 2050

Roadmap 2050 is a programme of research which is designed to provide an independent analysis of the 'pathways' to achieve a low-carbon economy in Europe in line with the energy security, environmental and economic goals of the EU (European Climate Foundation, 2010). The project is funded through the European Climate Foundation and the 'roadmap' is based on extensive technical, economic and policy analyses conducted by five consultancies: Imperial College London, KEMA, McKinsey & Company, Oxford Economics, and the Office of Metropolitan Architecture, in addition to the involvement of utilities, transmission operators and NGOs[2]. In the report the term 'pathway' is used (but also sometimes synonymously with 'scenario') to describe the varying trajectories of energy 'mix' to achieve an 80% EU-wide reduction in carbon emissions by 2050.

3.1.3 SETIS/Smart Cities

SETIS is the European Commission's Information System for the SET-Plan led by the Joint Research Centre. It supports the strategic planning and implementation of the SET-Plan. It makes the case for technology options and priorities, monitors and reviews progress regarding implementation, assesses the impact on policy, and identifies corrective measures if needed (SETIS, 2010). SETIS has two principal activities, which are based on its own transparent research:

- Technology mapping: key information on the status and prospects of low-carbon technology with respect to EU policy goals;
- Capacities mapping: an estimation of the current public and private research and development (R&D) expenditures across the EU-27 on the priority energy technologies.

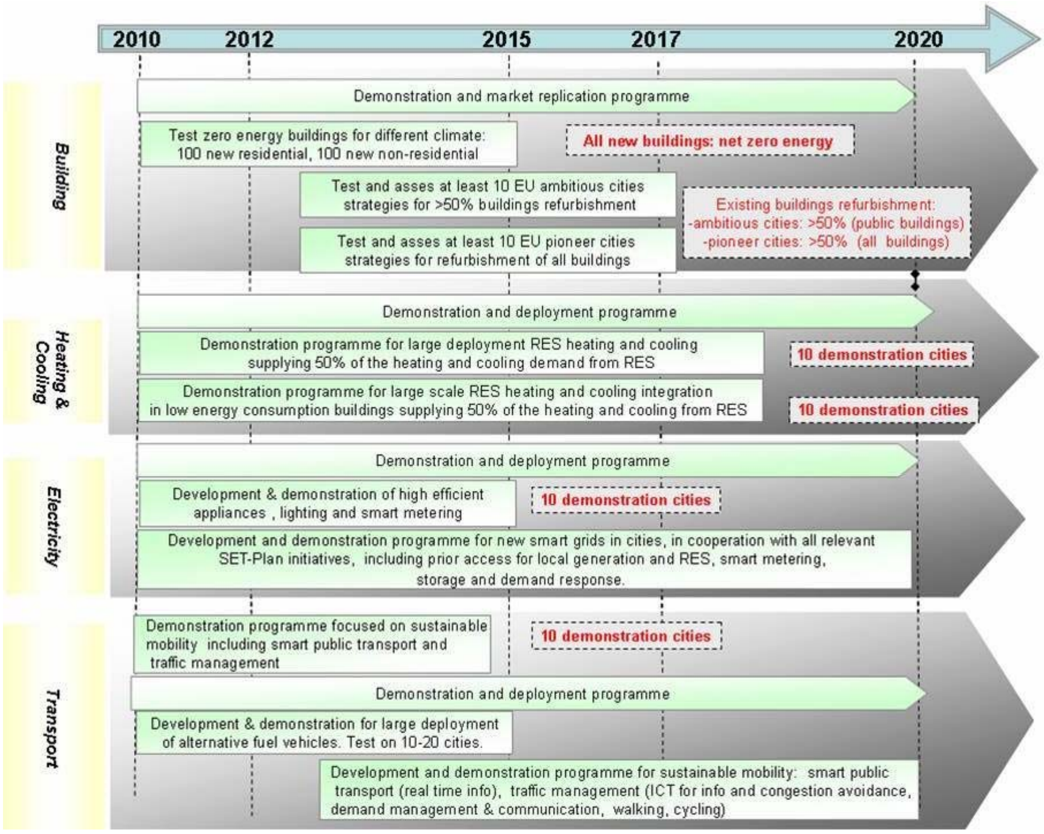
[2] See http://www.roadmap2050.eu/

A set of seven roadmaps are being produced to take Europe to a low carbon future by 2050 (including wind, solar, bioenergy, carbon capture storage, electricity grid, nuclear energy and ‘smart cities’). These are based on the following sectoral targets:

- Up to 20% of the EU electricity will be produced by wind energy technologies by 2020.
- Up to 15% of the EU electricity will be generated by solar energy in 2020. However if the
- DESERTEC vision (mass deployment of solar technology) is achieved, the contribution of solar energy will be higher, especially in the longer term.
- The electricity grid in Europe will be able to integrate up to 35% renewable electricity in a seamless way and operate along the "smart" principle, effectively matching supply and demand by 2020.
- At least 14% of the EU energy mix will be from cost-competitive, sustainable bio-energy by 2020.
- Carbon capture and storage technologies will become cost-competitive within a carbon pricing environment by 2020-2025.
- While existing nuclear technologies will continue to provide around 30% of EU electricity in the next decades, the first Generation-IV nuclear reactor prototypes will be in operation by 2020, allowing commercial deployment by 2040.
- 25 to 30 European cities will be at the forefront of the transition to a low carbon economy by 2020 (Smart Cities Initiative).

The Smart Cities Initiative (Figure 6) is important because it will support cities and regions in taking ambitious and pioneering measures to progress by 2020 towards a 40% reduction of greenhouse gas emissions through sustainable use and production of energy. This will require systemic approaches and organisational innovation, encompassing energy efficiency, low carbon technologies and the smart management of supply and demand. In particular, measures on buildings, local energy networks and transport would be the main components of the Initiative (Smart Cities, 2010). The Initiative builds on existing EU and national policies and programmes, such as CIVITAS, CONCERTO and Intelligent Energy Europe. It will draw upon the other SET-Plan Industrial Initiatives, in particular the Solar and Electricity Grid, as well as on the EU public-private partnership for Buildings and Green Cars established under the European Economic Plan for Recovery. The local authorities involved in the Covenant of Mayors (more than 500 cities) will be mobilised around this initiative to multiply its impact.

Figure 6 Smart Cities Initiative (Smart Cities, 2010)



4.0 Transitions

As Hughes (2009) argued a key deficiency with many low carbon scenario-based studies is their failure to describe the role of actors within the process of moving to a particular future end point. Hughes cites evidence from other literature (for example, Le Roux et al, 1992) to suggest that the motivations, decisions and actions of actors are vital to understand in determining the creation of ‘branch points’ where choices are made about a particular technology and its pathway for example. However, this produces a ‘linear’ trajectory characterised by ‘lock-in’ or ‘path dependence’. Therefore a ‘co-evolutionary’, ‘non-linear’ conceptualization has been advocated (Hughes, 2009, Rydin et al, 2010) which effectively promotes a more iterative, feedback model where actors hold centre stage.

There is also resonance here with the concept of ‘transitions theory’ which seeks to understand the processes by which socio-technical change occurs in society. As Hargreaves and Burgess (2009) suggest the term ‘transition’ has been used increasingly not only in academic literature but also in policy documents and civil society movements, including the UK’s ‘Transition Towns’. In the academic literature the term is frequently embedded within the framework and context of Frank Geel’s Multi-Level Perspective (see for example, Geels (2005)). In this sense the term transition has been defined by Rotmans and Loorbach (2009:184) as:

‘a structural change in a societal (sub)system that is the result of a co-evolution of economic, cultural, technological, ecological and institutional developments at different scale levels’.

For Rotmans and Loorbach (2008), transitions cannot be steered in command and control terms because of their complexity and uncertainties, but they can be influenced and guided in terms of their speed and direction through ‘transition management’.

Much of the thinking behind this has evolved in the Netherlands and is a response to the complexities and socio-technical responses needed to plan and manage the substantial societal and institutional change required for sustainability. The work of Frank Geels (see for example, Geels 2005; 2004[3]) has been seminal in this respect in identifying three interlocking levels where innovation occurs, and which set out and define the landscape or terrain over which transitions to sustainability occur (Shackley and Green, 2007). These comprise what is called an integrative multi-level perspective (Geels, 2004), and the model draws on ecology, political science and evolutionary biology literature (Hughes, 2009).

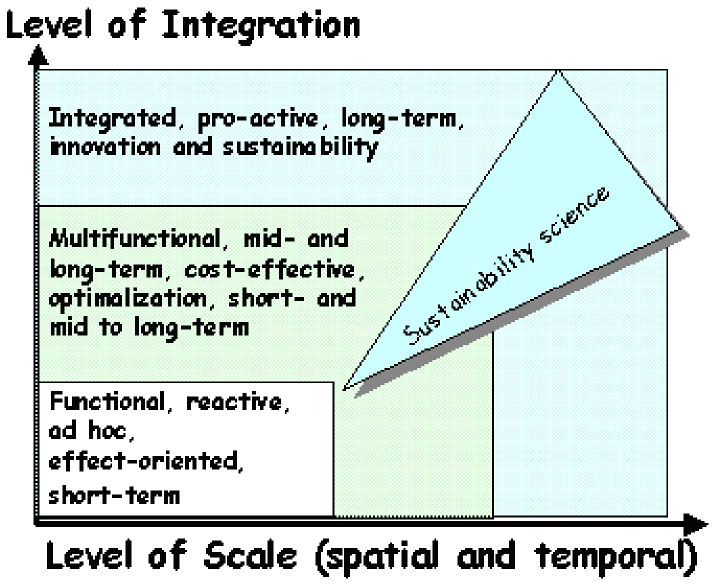
For Martens (2006: 39) transition management is a *'visionary, evolutionary learning process'* that is constructed by undertaking the following steps:

- Developing a long-term vision of sustainable development and a common agenda (macro scale)
- Formulating and executing a local experiment in renewal that can contribute to the transition to sustainability (micro-scale).
- Evaluating and learning from these experiments
- Assembling the vision and the strategy for sustainability based on what has been learned: this constitutes a new style of planning-'learning by doing' and vice versa.

McDowall and Eames (2006) identify two types of 'visions' in relation to hydrogen futures. Firstly those produced by individuals or groups outlining a desirable future and secondly those produced through workshops to provide the basis for roadmapping. Outside the context of transition theory, however, such visions have often failed to address the dynamics of change.

Visions and the issue of scale are therefore important (Kemp and Martens, 2007). Visions can map a range of alternatives, and can help guide problem-solving, as well as acting as a framework target-setting and monitoring progress. However, moving towards a future vision requires aiming for short term gaols alongside a more innovative approach to future thinking (Figure 7).

Figure 7 The role of sustainability science in the policy process (Martens, 2006)



3 See also: http://www.sussex.ac.uk/profiles/228052

5.0 Pathways

Within the transitions literature the concept of a 'pathway' is important to recognise. For Hughes (2009) pathways seek to develop well-established technological and economic scenario-building techniques by focusing on the co-evolution of actors and technological infrastructure in transition processes. In short (Hargreaves and Burgess 2009: 20):

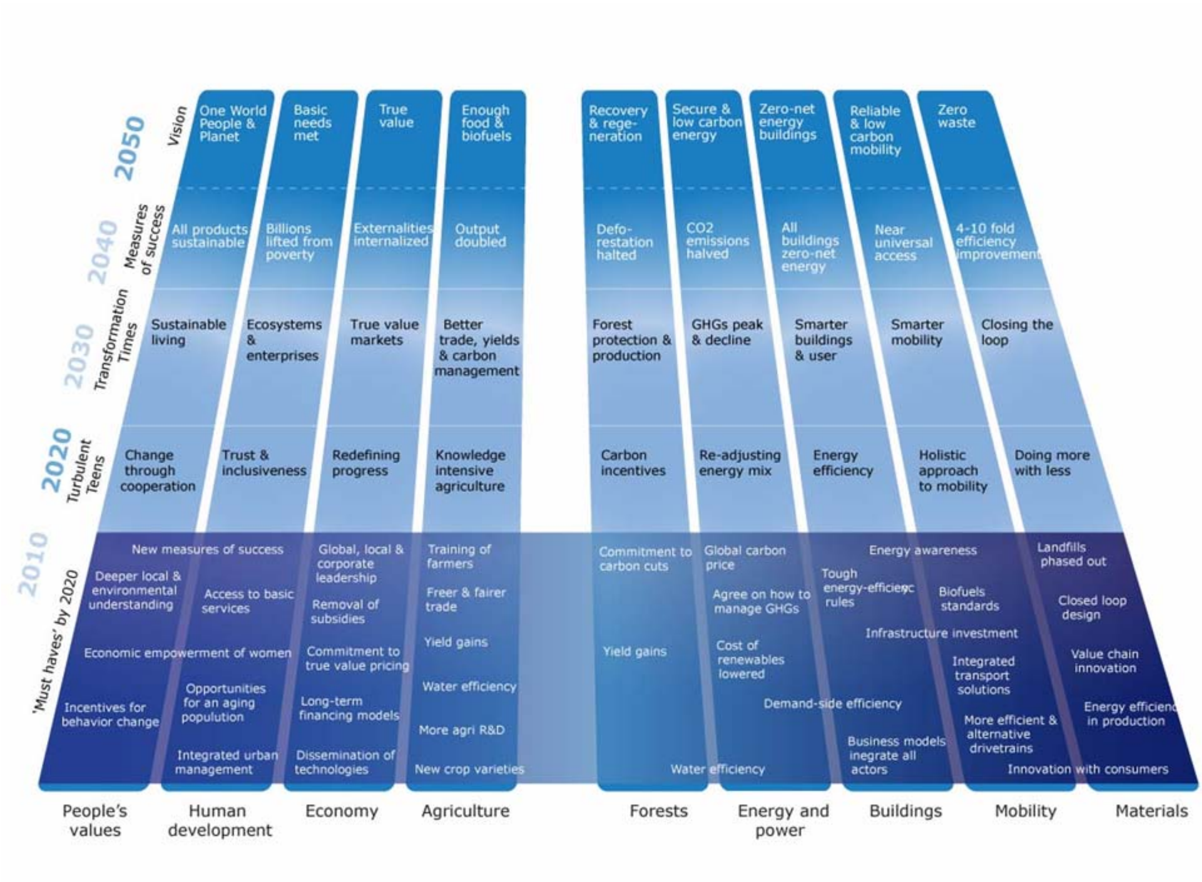
'Pathways seek not only to discover if different futures are technically and economically feasible but how such futures might plausibly be brought about by different social actors'.

Although the Low Carbon Transition Pathways project found, based on an extensive analysis of low carbon studies, *good* scenarios *are* transition pathways (Hargreaves and Burgess, 2009), there were differences in understanding within the research team over whether pathways were normative and whether they provide robust frameworks for more quantitative modelling. Indeed Geels and Schot (2007) suggest there are a range of pathways in transition theory based on the timing of interaction between niches, regimes and landscapes. These comprise:

- Transformation, brought about by external pressures and gradual adjustment.
- Reconfiguration, characterised by incremental and reconfigured niche developments.
- Technological substitution, created by landscape pressures and regime tensions which create windows of opportunity for niche innovations.
- De-alignment and re-alignment, created by major landscape changes and critical regime problems.

Interestingly the recent DECC 2050 Pathways Analysis (HM Government, 2010) uses terminology such as 'pathways' and 'transition' in the context of modelling various future combinations of energy mix. However, on closer examination it is clear that the analysis uses four main trajectories to develop a variety of pathways using energy supply mixes to achieve a target of 80% carbon emissions by 2050. In other words the study is very much scenario-based and with no co-evolutionary focus. Again the recent World Business Council for Sustainable Development (2010) report, *Vision 2050*, does not focus on transition theory and simply acknowledges that a pathway is *'a set of descriptions that illustrates the transition to a certain scenario'* without any detailed analysis of social or governance elements. The study uses two time frames: the 'turbulent teens' to 2020 and 'transformation time' from 2020 to 2050 to act as foci for backcasting from 2050 and identifying the changes needed to reach the future (Figure 8).

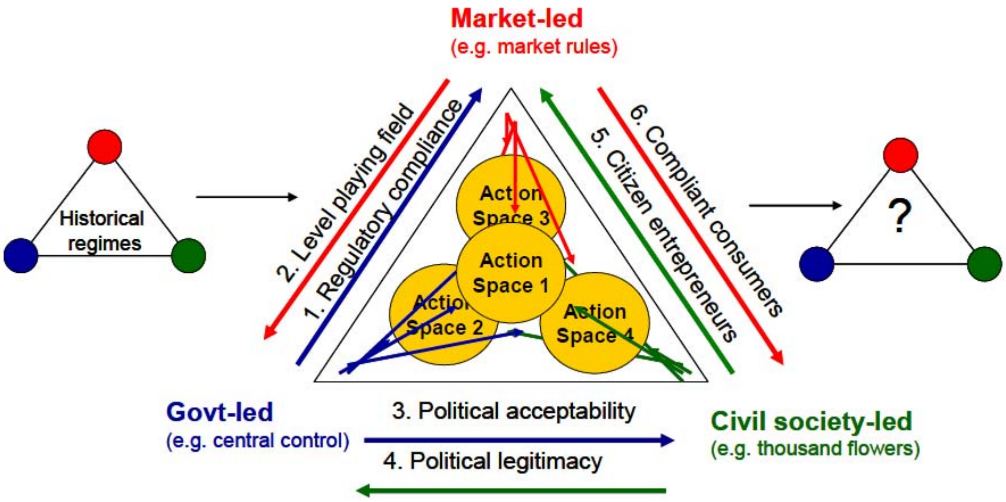
Figure 8 Vision 2050 (WBCSD, 2010)



McDowall and Eames' (2006) of hydrogen studies found evidence of the linkage between backcasts and pathways in which a future vision is outlined and storylines worked back from the vision to the present. At the time of their review, however, the studies they examined in this group did not generally include reference to transitions theory per se, although a more recent study by the authors themselves (Eames and McDowall, 2010) uses vision-based techniques within a transitions theory approach (building on the sustainability foresight methods of Truffer, Voss and Konrad, 2008) in order to explore pathways to a hydrogen-based future in the UK.

In contrast, the EPSRC Transition Pathways project attempts to combine governance structures within a transitions framework. The conceptualisation is shown in Figure 9.

Figure 9 Action space for transition pathways (source: Foxon et al, 2010)



Within this framework there are three main groups of actors (government-led; market led, covering integrated supply companies and smaller market-based actors; and civil society-led, which includes end users and other civil society actors such as trade unions, the media and so on) (Foxon et al, 2010). These actors are located within an 'action space' in which the current energy regime sits, and different kinds of relationship and different kinds of transition can occur depending on changing power relations between the actors.

This framework is then used to explore different 'pathways' which are based on differing governance patterns, which are a function of the relative power and the mix and balance of centralized and decentralised decision-making within energy systems. These pathways are based on the team's insight, stakeholders' insights via workshops, interviews and additional modelling and foresight. This has produced three initial pathways which are shown in Table 9.

Table 9 Low Carbon Transition Pathways (Foxon et al, 2010)

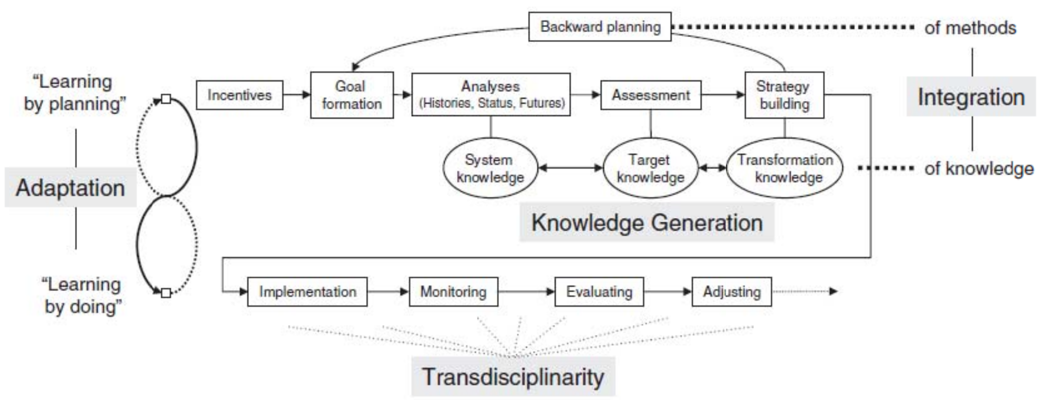
Pathway	
'Market Rules'	Broad continuation of the current market-led governance pattern, in which the government specifies the high level goals of the system and sets up the broad institutional structures, in an approach based on minimal possible interference in market arrangements.
'Central Co-Ordination'	Greater direct governmental involvement in the governance of energy systems, applying some of the principles of transition management.
'Thousand Flowers'	A sharper focus on more local, bottom-up diverse solutions ("let a thousand flowers bloom"), driven by innovative local authorities and citizens groups, such as the 'Transition Towns' movement to develop local micro-grids and energy service companies.

6.0 Making linkages: Scenarios, Roadmaps, Transitions, Pathways and Knowledge Mapping

For Wiek et al (2006) transition management has four key requirements (Figure 10) which include:

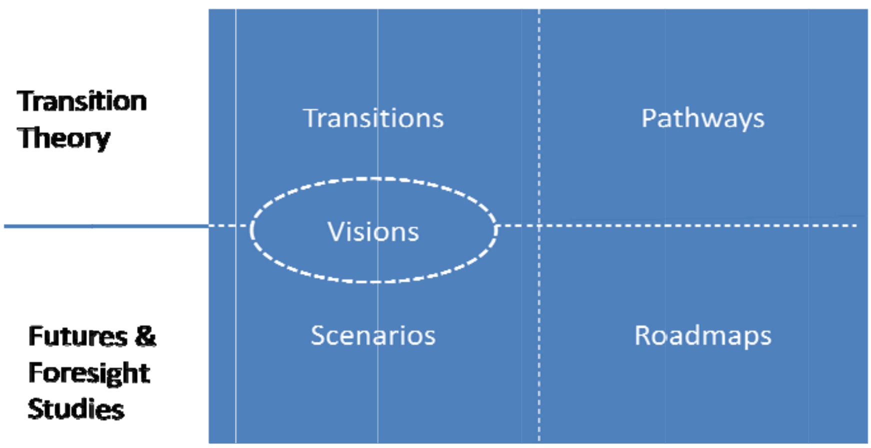
- Knowledge generation, including system knowledge, target knowledge, and transformation knowledge.
- Integration, which links knowledge generation with systems planning.
- Adaptation, which links planning and learning.
- Transdisciplinarity, which brings together a range of stakeholders.

Figure 10 Requirements of transition management (Wiek et al, 2006)



Wiek et al (2006) also suggest that scenarios can play an important role in underpinning these four phases of transition management. However, it is clear from what has been described before that in many cases the terminology can sometimes be 'fuzzy' and 'blurred' in low carbon futures studies. On the other hand, it seems to be the case that transitions literature is frequently characterised by the use of the terms, 'transitions' and 'pathways' whereas futures/foresight studies tend to be based around 'scenarios' and 'roadmaps'. This is by no means an immutable rule, however, and in practice as we have also seen, there is overlap and linkage between the four quadrants identified in Figure 11, particularly in relation to the use of 'visions'.

Figure 11 Conceptualising techniques in transition theory and futures/Foresight studies



What is also clear is that mapping existing knowledge is a cornerstone of both transitions-based and scenario-based techniques. Jabereen (2004; 2009) uses metaphor making, for example, to discover patterns, themes and metaphors in the literature of sustainable development in order to construct a knowledge map. As a result a conceptual framework of sustainable development is constructed which identifies seven concepts: equity; natural stock capital; integrative; utopia; 'eco-nomics'; eco-form; and global agenda. A variety of visual techniques may also be subsequently employed to represent the knowledge map (Eppler and Burkhard, 2007).

Knowledge mapping is also at the heart of UK Foresight techniques. For example, 'expert reviews' are commissioned to identify the state of current science and future advances. This includes an analysis of data and trends; key challenges; key scientific advances and a discussion of the current state of scientific understanding which would include:

- Key variables and system components.
- Interconnections.
- Critical issues of change or uncertainties.

Mapping technologies for sustainable development also requires a generic framing. Mulder (2007) for example suggest that all new technologies entail social change and that the successful introduction of a new technology is a matter of socio-technical change. To that extent technologies for sustainable development can be classified according to particular characteristics (Table 10).

Table 10 Environmental classification of technologies (Mulder 2007)

Technology type	Function	Resources predominantly used	Resource efficiency	Emissions	Impact on natural systems
1. Preindustrial technologies	To provide	Renewable	Low to high	Low	Some overexploitation, often compensated by low density of population
2. Classic environmental technologies	To prevent harm by pollution	Nonrenewable	Low	High	Ecological destruction outside settlements
3. Good housekeeping technologies	To mitigate pollution	Nonrenewable	Medium to low	Medium to low	Mitigation of ecological destruction
4. End-of-pipe technologies	To prevent pollution after process	Nonrenewable	Medium to low	Low	Less pollution, at the expense of extra resource use
5. Process adaptation/damage prevention	To prevent pollution arising in process	Nonrenewable and renewable	High	Low	Less pollution and less resource use
6. Sustainable technologies	To provide within the limits of the earth's carrying capacity	Renewable	High	None	Balance between humanity and the natural environment

7.0 Conclusions: implications for RETROFIT 2050

In this discussion and overview of low carbon scenarios, roadmaps, transitions and pathways it is clear that the distinctions between the techniques have often been blurred in the field of low carbon futures studies. Visions, for example, have been used in both transition theory and futures/Foresight methods, and scenarios have also been used in transition-based studies as well as futures/Foresight studies.

Nonetheless, in summary, the terms may be distinguished as follows:

- Scenarios use imagination to consider possible future alternatives. Often based on a '2x2' matrix in the Foresight model they can be formulated inductively by identifying key drivers for change and key uncertainties (i.e. in terms of 'x' and 'y' axes), or deductively by high level group work. Many scenarios-based studies lack a 'co-evolutionary' perspective (i.e. or a recognition that technology interacts with social, cultural and political systems).

- Roadmaps take an extended look at the future, based on extensive analysis of drivers of change in the field of analysis. They frequently focus on demand and supply issues and technology pull and push but may suffer from linear thinking. Some roadmaps use 'visions' to identify plausible futures.
- Transitions represent structural changes in society which is the result of co-evolutionary forces. They often employ visions and are an important component of transition theory.
- Pathways often start with a plausible future and then backcast to the present. In pure transitions theory, pathways seek to develop co-evolutionary thinking to bring about future change.
- Visions are elaborations of a desirable and plausible future and may feature in both Foresight work and Transitions-based studies.

In the low carbon arena there is a preponderance of scenario-based future studies which frequently use a '2x2' matrix and arrive at scenarios which have strong similarities: governance and sustainability 'uncertainties', for example, are strongly represented. The EPSRC Low Carbon Transition Pathways model, which conceptualises an 'action space', offers the benefits of linking scenario-based approaches with a strong co-evolutionary approach.

Scenario choice is often dealt with flexibly in many studies and some authors suggest that using 'off the shelf' pre-existing scenarios can help in some circumstances. However, developing scenarios from first principles has the advantage of a 'bespoke' methodology. Foresight techniques which capture expert knowledge and map existing knowledge to develop a set of scenarios and roadmaps which can inform the development of transitions and pathways therefore helps potentially overcome any 'disconnections' that may exist between the social and the technical lenses in which such future trajectories are mapped.

References

Arup (2010) *Research Roadmap 2010*. Arup (accessed November2010 from http://www.arup.com/Publications/Research_Roadmap.aspx)

CURE (2007) *Peri-Urban Land Use Relationships; Driving Forces and Global Trends-Module 1*. Centre for Urban & regional Ecology, University of Manchester.

Eames, M., and McDowall, W. (2010) 'Sustainability, foresight and contested futures: exploring visions and pathways in the transition to a hydrogen economy', *Technology Analysis & Strategic Management*, 22, 6, 671-692.

Eppler, M., and Burkhard, R. (2007) 'Visual representations in knowledge management: framework and cases', *Journal of Knowledge Management*, Vol 11 No 4, 112-122.

European Climate Foundation (2010) *Roadmap 2050: Executive Summary* (accessed November 2010 from http://www.roadmap2050.eu/)

Foxon, T., Burgess, J., Hammond, G., Hargreaves, T., Jones, C., and Pearson, P. (2010) 'Transition pathways to a low carbon economy: linking governance patterns and assessment methodologies', *IAIA10 Conference Proceedings, The Role of Impact Assessment in Transitioning to a Green Economy*, 6-11 April, Geneva, Switzerland.(Accessed November

2010 from: http://www.iaia.org/iaia10/documents/reviewed_papers/Transition%20Pathways%20to%20a%20Low%20Carbon%20Economy.pdf)

Gallopin, G., Hammond, A., Raskin, P., and Swart, R. (1997) *Branch Points: Global Scenarios and Human Choice. A Resource Paper for the Global Scenario Group*. Stockholm Environment Institute.

Galvin, R. (2008) 'Science roadmaps', *Science*, 280 (5365), 803

Geels, F. (2005) 'Processes and patterns in transitions and system innovations: Refining the co-evolutionary multi-level perspective', *Technological Forecasting and Social Change*, 72,681-696.

Geels, F. W., and Schot, J. (2007) 'Typology of sociotechnical transition pathways.' *Research Policy*, 36, pp. 399-417.

Geels, F.W. (2004) 'From sectoral systems of innovation to socio-technical systems: insights about dynamics and change from sociology and institutional theory', *Research Policy*, 33, 897-920.

Hargreaves, T., and Burgess, J. (2009) *Pathways to Interdisciplinarity: A Technical Report Exploring Collaborative Interdisciplinary Working in the Transition Pathways Consortium*. (accessed November 2010 from: http://www.uea.ac.uk/env/cserge/pub/wp/edm/edm_2010_12.htm)

HM Government (2010) *2050 Pathways Analysis* (Accessed November 2010 from: http://www.decc.gov.uk/en/content/cms/what_we_do/lc_uk/2050/2050.aspx)

Hughes , N., Mers, J., and Strachan, N. (2009) *Review and Analysis of UK and International Low Carbon Energy Scenarios. Joint Working paper of UKERC and Eon.UK/EPSRC Transition Pathways Project*. (Accessed November 2010 from: http://www.lowcarbonpathways.org.uk/lowcarbon/publications/)

Hughes, N. (2009) *A Historical Overview of Strategic Scenario Planning and Lessons for Undertaking Low Carbon Energy Policy*. *Joint Working paper of EON/EPSRC Transition Pathways Project (Working Paper 1).* (Accessed November 2010 from: http://www.lowcarbonpathways.org.uk/lowcarbon/publications/)

INSIS (2009) *Oxford Programme for the Future of Cities: Emerging Research Themes. Institute for Science, Innovation and Society*, Said Business School/Martin Oxford School, Oxford University.

Jabareen, Y. (2004) 'A knowledge map for describing variegated and conflict domains of sustainable development', *Journal of Environmental Planning and Management*, Vol 47, No 4, 623-642.

Jabareen, Y. (2009) ‘Building a Conceptual Framework: Philosophy, Definitions, and Procedure, *International Journal of Qualitative Methods,* 8(4), 49-62

Kemp, R., and Martens, P. (2007) ‘Sustainable development: how to manage something that is subjective and never can be achieved?’ *Sustainability: Science Practice and Policy*: Fall, Vol 3 No 2, 5-14

Le Roux, P. (1992) *The Mont Fleur Scenarios. Weekly Mail and The Guardian Weekly* (accessed November 2010 from: http://www.generonconsulting.com/publications/papers/pdfs/Mont%20Fleur.pdf)

Loveridge, D. (2001) ‘Foresight-seven paradoxes’, *International Journal of Technology Management*, 21, 7/8, 781-91

Loveridge, D. (2009) *Foresight: The Art and Science of Anticipating the Future*. Routledge.

Martens, P. (2006) ‘Sustainability: science or fiction?”, *Sustainability: Science Practice and Policy*: Spring, Vol 2 issue 1, 36-41

McDowall, W., and Eames, M. (2006) ‘Forecasts, scenarios, visions, backcasts and roadmaps to the hydrogen economy: A review of the hydrogen futures literature’, *Energy Policy*, 34, 1236-1250.

Miles, I., and Keenan, M. (2002) *Practical Guide to Regional Foresight in the United Kingdom*. European Commission.

Mulder, K. (2007) ‘Innovation for sustainable development: from environmental design to transition management’, *Sustainability Science*, 2: 253-263.

O’Brien, G., Brodowicz, D., and Ratcliffe, J. (2009) *Built Environment Foresight: The Sustainable Development Imperative.* The Futures Academy, Dublin Institute of Technology.

Outsights/Thomson Reuters (2009) *Real Estate Investment Management 2020 and Beyond Workshop Report*. June. Outsights/Thomson Reuters.

Phaal, R. (2008) *Technology and Other (Mostly Sector-Level) Published Roadmaps.* Institute for Manufacturing and University of Cambridge.

Phaal, R., and Probert, D. (2009) *Technology Roadmapping: Facilitating Collaborative Research Strategy.* Centre for Technology Management, Dept. of Engineering, University of Cambridge.

PLUREL (2008) ‘Scenarios: crystal balls for the urban fringe’, *Newsletter.* April (Accessed November 2010 from: http://www.plurel.net/images/PLUREL_%20newsletter_No%203_screen.pdf)

Rotmans, J., and Loorbach, D. (2008) 'Transition management: reflexive governance of societal complexity through searching, learning and experimenting', in van den Bergh, J., and Bruinsma, F. (eds) *Managing the Transition to Renewable Energy*. Edward Elgar.

Rotmans, J., and Loorbach, D. (2009) 'Complexity and Transition Management', *Journal of Industrial Ecology*, Vol 13 No 2, 184-196

Rydin, Y., Thomas, S., and Beddington, J. (2010) 'Briefing: Energy and the built environment', *Urban Design and Planning*, 163, Issue DP3, 95-99

Saritas, O. (2006) *Systems Thinking for Foresight*. PhD Thesis for PREST, University of Manchester.

Saritas, O., and Aylen, J. (2010) 'Using scenarios for roadmapping: the case of clean production', *Technological Forecasting & Social Change*, 77, 1061-1075

Saritas, O., and Oner, M.A. (2004) 'Systemic analysis of UK Foresight results: joint application of integrated management model and roadmapping', *Technological Forecasting & Social Change*, 71, 27-65

SETIS (2010) *Strategic Energy Technologies Information System* (website accessed November 2010 from http://setis.ec.europa.eu/)

Shackley, S., and Green, K. (2007) 'A conceptual framework for exploring transitions to decarbonised energy systems in the United Kingdom', *Energy*, 32, 221-236.

Smart Cities (2010) *European Initiative on Smart Cities* (accessed November 2010 from http://setis.ec.europa.eu/about-setis/technology-roadmap/european-initiative-on-smart-cities)

Strategy Unit (2004) *Strategy Survival Guide: Looking Forward-Scenario Development* (accessed November 2010 from www.cabinetoffice.gov.uk)

Truffer, B., Voss, J., and Konrad, K. (2008) 'Mapping expectations for system transformations: Lessons from Sustainability Foresight in German utility sectors, *Technological Forecasting & social Change*, 75, 1360-1372.

UK Government Office of Science (2008) *Powering our Lives: Sustainable Energy Management and the Built Environment-Futures Report* Government Office for Science/Foresight

Urban Futures (2008) *Progress Update for Urban Futures*. Civil Engineering Department, University of Birmingham (accessed November 2010 from http://www.urban-futures.org/)

WBCSD (2010) *Vision 2050.* World Business Council on Sustainable Development.

Wiek, A., Binder, C., Scholz, R.W. (2006) 'Functoions of scenarios in transition process', *Futures,* 38, 740-66.