Water Policy 15 (2013) 212–222

Dealing with future challenges: a social learning alliance in the Dutch water sector

Jos Frijns*, Chris Büscher, Andrew Segrave and Mariëlle van der Zouwen

KWR Watercycle Research Institute, P.O. Box 1072, 3430 BB Nieuwegein, The Netherlands
**Corresponding author. E-mail: jos.frijns@kwrwater.nl*

Abstract

This paper presents 10 prominent trends, from economic instability to social networking, that have been signalled as likely to challenge the water sector. These trends can be characterised as complex, uncertain, diverse and interconnected. To arrive at meaningful responses to these challenges, actors increasingly employ integrated, adaptive or participatory approaches, or a mixture of these. This paper highlights an example of such an approach in the Netherlands, in which participatory backcasting and social learning have been used as methods to develop response strategies. It appears that, through a process of co-learning, conceptual building-blocks are created for response strategies to deal with the future challenges of the water sector.

Keywords: Futures studies; Knowledge co-production; Participatory backcasting; Response strategy; Social learning; The Netherlands; Trends; Water sector

1. Introduction

The context of the water sector changes continuously. At the same time, individual organisations within the sector are striving to be sustainable. The challenge is to strike a balance between the anthropogenic and natural systems while meeting the needs of the population. Organisations within the water sector are planning to prepare for pressing issues such as rising energy costs, expanding regulations, changing workforce and efficiency drivers. For these organisations to develop strategies towards resilient service provision, they require insights into future trends and challenges, and knowledge and response strategies to deal with these developments. Futures research provides the water sector with a strategic understanding of relevant developments that act as building-blocks for the design of their corporate strategies.

doi: 10.2166/wp.2012.036

In this paper, futures research activities in the Dutch water sector are presented in two stages:

(i) identification of relevant trends and challenges for the Dutch water sector; and
(ii) identification of meaningful response strategies for Dutch water organisations.

As traditional cause and effect strategic planning does not work well in today's dynamic world (Brueck, 2005), the second stage entails carefully designed transdisciplinary, co-production activities involving both water organisation professionals and researchers. It is based on participatory backcasting (Kok *et al*., 2011; Robinson *et al*., 2011) and social learning (Pahl-Wostl *et al*., 2007; Wals, 2007).

The two stages are addressed here by presenting both the methods employed and the results obtained. Section 2 presents the activity of identifying trends and accompanying challenges. Section 3 addresses the development of response strategies as a co-production between water organisation professionals and researchers. Section 4 presents the experience gained within the Dutch Water Sector Intelligence (DWSI) platform.

2. Identifying relevant trends and challenges

2.1. Scanning the horizon

At the KWR Watercycle Research Institute, the trends and future challenges for the water sector are continuously monitored. The method applied to identify relevant trends and challenges is summarised in Table 1 and further explained below.

To improve the quality of political and administrative decision-making, national planning agencies conduct outlook studies, analyses and evaluations. In the Netherlands, planning agencies for environmental assessment, economic policy analysis and social research frequently publish studies about future developments in relevant areas of government policy. Likewise, research and technology institutes perform scenario analysis and technology forecasts in their respective fields of expertise. Similar futures studies are also conducted elsewhere in Europe and organisations like the European Foresight Platform monitor ongoing and emerging developments. Internationally, United Nations institutions and network organisations such as the World Future Society explore the future and publish frequent trend reports.

Our horizon-scanning activities draw on these national and international future studies by examining the so-called SEPTED dimensions of development: social, economic, political, technological, ecological

Table 1. Method for identifying trends and challenges.

Dimensions	Sources	Analysis	Result
Development in: • Social • Economic • Political • Technological • Ecological • Demographic	Futures studies and scenarios from: • Planning agencies • Network organisations • Research and technology institutes	Exploring: • Relevance for water sector (impact) • Opportunities and risks	Trend alerts: • Summary description of trend • Challenges for Dutch water sector

and demographic trends. We gather and analyse such reports and summarise them in trend alerts for the Dutch water sector, providing concise descriptions of the developments and their relevance to the sector. These trend alerts provide an overview of the key societal and technological developments, and address how these challenges should be dealt with, i.e. how to deal with uncertainty, and what are the opportunities and risks for the water sector.

2.2. Ten prominent developments

From the trend alerts in the period 2010–2011 we selected the following 10 prominent developments that we consider relevant for the Dutch water sector. These 10 trends have not been prioritised in terms of certainty and impact but merely serve to illustrate challenges for the water sector. More importantly, these trends are used to discuss what may constitute effective response strategies for water organisations.

2.2.1. Unstable economic development. The European economic crisis puts a strong burden on society and the water sector is confronted with cuts in investments. In the Dutch water sector, financial gain is anticipated by more efficient collaboration among the sectoral parts of the water cycle, in particular between sewerage and wastewater treatment. In this way, financial cutbacks stimulate economic reductionist decision-making and serve as an important driver for further collaboration in the water sector. A related development is the efficiency drive within water companies themselves. New public management (Veenswijk, 2005) and private sector principles are taking shape in the water industry. Benchmarking and performance improvement have become key operating principles, with mixed results.

2.2.2. Citizens' engagement. Citizens, or consumers, in spite of the high service level of Dutch drinking water companies, are becoming increasingly critical and demanding. Although water is clearly a low interest product, consumers consider water to be an element in high interest topics such as health, wellness and convenience. Drinking water companies thus increasingly face the challenge of making the shift from a mere water supplier towards a customer-oriented service provider. In particular, opportunities exist for new services to contribute to sustainability (Hegger *et al.*, 2011). For water boards (regional water authorities) in the Netherlands, the situation is different. Traditionally, citizens and water boards have been closely connected. Citizens pay taxes and can vote for the candidates for water boards. Citizens increasingly expect water boards to accommodate their wishes, ideas, complaints and initiatives. Partly driven by the need for participatory water management under the EU Water Framework Directive, water boards are responding to these expectations by involving organised stakeholder groups into decision-making processes. There are, however, many individual citizens whose views and ideas are not represented in these groups. Particularly in relation to local projects which have an impact on landscapes in citizens' backyards, water boards face the challenge of actively dealing with the perceptions of non-organised citizens in water management.

2.2.3. Demographic change. A growing number of people are living longer than ever before. Societies must adapt to allow for their ageing populace. One of the effects for the water sector is the increase in medicine use and the consequent efforts necessary to remove medicine residues from the water system. In addition to changes in the age structure of the population, the Netherlands will also have to deal with regional population decline. For areas facing a population decline, decentralised water systems could become feasible options for cost-effective service provision. Demographic changes and their time–space variations also increase the uncertainty of the anticipated long-term future water demand (Wuijts *et al.*, 2011).

2.2.4. Sustainability. The move towards sustainable development seems likely to continue. Climate change, for example, remains top of the agenda. The European water sector is actively reducing its energy consumption and maximising the potential energy recovery (heat) and production (biogas) (Frijns *et al.*, 2012). An analysis of the Dutch water cycle showed that an energy-neutral water cycle is achievable if the thermal and chemical energy content of wastewater is recovered (Hofman *et al.*, 2011). Also, major technology innovations are anticipated to enhance nutrient recovery (especially of phosphate) from domestic and industrial wastewater. Further steps can be expected for new sanitation concepts in which water, energy and nutrient 'up-cycling' (according to cradle-to-cradle principles) will be applied (Nederlof *et al.*, 2010). Finally, 2010 was the International Year of Biodiversity and major challenges for the water sector lie ahead with respect to nature conservation.

2.2.5. Resource use and shortages. The prevailing high prices of food, oil and many other resources such as minerals and rare earth elements indicate increasing scarcity. This scarcity results from overconsumption in Western countries (UNEP, 2011) and from badly functioning markets and inept policy reactions (PBL, 2011). Also, in large parts of the world (including the Netherlands), water has or will become a scarce resource (EEA, 2009). This necessitates water conservation, reduction of the water footprint of products, efficiency gains in irrigation, and technology progress in (underground) water storage, distribution system loss reduction, decentralised capture (rainwater tanks), water reuse and sea water desalination. Political commitment is essential for obtaining these goals.

2.2.6. NBIC converging technologies. Pivotal new technologies are emerging in the fields of nanotechnology, biotechnology, information technology and cognitive sciences (NBIC). The developments in these technologies not only complement each other, but the fields are gradually merging (Swierstra *et al.*, 2009), with nanotechnology often being the catalyst. Relevant examples include smart materials, lab-on-chip, neural networks, synthetic biology, smart grids, active nanostructures, geo-information systems, resistant bacteria and augmented reality. Many of these will find their way into, for example, the practice of water sensoring, treatment technologies and water distribution.

2.2.7. Trans-sectoral innovation. There is much scope for cross-fertilisation and innovation not only at the intersections between fields of technology but also between and beyond sectors. The incorporation of shower heat exchangers in the Dutch construction sector to realise low-energy houses is one pertinent example. In fact, the driving forces for transformation could well be much stronger in other sectors than the water sector. There is an urgent need for modification in the energy, housing, construction and urban planning sector to adapt to anticipated climate change. This is an opportunity for those in the water sector to link their efforts with these transformations and have water incorporated in major revisions, e.g. in urban renewal (van der Brugge & de Graaf, 2010).

2.2.8. Shifts in governance. Two inter-related developments in governance have increased the complexity of water management. First, in the move from 'government' to 'governance', influence on decision-making is increasingly shared by both state- and non-state actors. Consequently, who has authority and responsibility over water tasks becomes more diffuse (Pierre & Peters, 2000). Second, the governance of water has become increasingly multi-level with decision-making power being dispersed among actors at different levels (Hooghe & Marks, 2001). When water management is considered as a multi-level exercise, collective leadership across levels is important. A typical example is the change in policy on biodiversity, which currently receives very low priority from the Dutch government but which, at the same time, is at the top of the EU environmental policy agenda. The challenge for the water sector is to retain its own vision and responsibility for its desired public tasks. This calls for collective leadership in the water sector.

2.2.9. City level. Most of the aforementioned developments are especially evident at the city level. It is in the cities where opportunities exist for economic development and innovations, and simultaneously in the cities where problems such as unsustainable consumption and ageing infrastructure are most prevalent. The urban metabolism concept shows that critical resources of the water cycle and other related cycles (energy, nutrients, materials) interact in cities (Pamminger & Kenway, 2008). It is in cities that the water sector should interact with other sectors to discuss common challenges and develop shared solutions. An inspiring example is provided by Steel (2008) who discusses the water–food–energy nexus in 'hungry cities'.

2.2.10. Social networking and the Internet of Things. Finally, the top trend at the moment is social networking and the use of social media such as smart phones. In the public domain we are surrounded by ever greater densities of digital equipment, with communication between devices and between people and devices; i.e. the 'Internet of Things' (van't Hof *et al.*, 2011). These rapid developments confront the Dutch water sector with major questions regarding their communication strategy and data management: should they embrace the open source movement and make available all raw data about, for example, water quality, or should they selectively share information with society? Should they have a proactive or reactive strategy on social media? How can they maintain authority as a water organisation when positions are called into question via social media? How can they engage citizens in water management using the increasing possibilities that the Internet of Things provides? These are only some examples of the many questions that confront the water sector as a result of the rapidly emerging importance of the virtual world. Examples already applied in practice include environmental monitoring systems, flood warning apps, and online information about water-borne disease outbreaks.

3. Developing co-produced response strategies

3.1. Wicked problems and interconnected developments

Most of the current problems and future challenges described above can be characterised by complexity, uncertainty and diversity – so called 'wicked' problems (Rittel & Webber, 1973; Lach *et al.*, 2005). Clearly defined boundaries are lacking; there is no definitive solution and different values and views can lead to conflicting strategies. Moreover, most developments are interconnected, i.e. problems (such as climate change and political shifts) and possible solutions (such as energy transition and NBIC convergence) interact with each other. Indeed, taken together the developments make up a wicked problem in themselves.

Complexity and uncertainty increase if sustainability is included as a central goal for water companies (Swart *et al.*, 2004). Wicked problems ask for an integrated, adaptive and participatory approach to water management (Segrave *et al.*, 2011). Current water policies are beginning to recognise this, yet the rhetoric is often not translated into practice. Traditional approaches to planning rest on certainties and knowledge of initial conditions to make probabilistic predictions. To deal with uncertainty in strategic planning in the water sector, an adaptive perspective is often taken (Pahl-Wostl *et al.*, 2007), focusing on an incremental adaptation of existing structures as a reaction to unforeseen developments. But if frequent adaptation is costly, as with investments in infrastructure, robust solutions are needed.

Addressing wicked problems requires participatory integrated approaches (Pahl-Wostl *et al.*, 2007) that have a long-term future and system orientation (Quist *et al.*, 2011). The involvement of stakeholders is needed for endorsement and legitimacy, and because they possess essential knowledge and resources. Pahl-Wostl *et al.* (2007) stress that all steps in the process of policy development and implementation should be participatory. Also, in water management, a multitude of participatory forms of modelling, planning, scenario development, backcasting and decision-aiding processes are being applied (van Korff *et al.*, 2012). In particular, participatory backcasting (in which roadmaps towards an envisaged system innovation are being developed through stakeholder dialogue) is applied in addressing wicked problems, e.g. in transitions towards sustainability (Quist *et al.*, 2011; Robinson *et al.*, 2011). Two striking examples are:

- participatory scenario planning and backcasting in a nature conservation project in Spain, which proved to be a good way of employing the diversity of perspectives and the openness of the future (Palomo *et al.*, 2011); and
- the participatory backcasting and scenario development which appeared to be well-suited to the challenges posed by the European Water Framework Directive for developing a long-term view by involving stakeholders (Kok *et al.*, 2011).

The benefits of participatory water management include (van Korff *et al.*, 2012): better-quality decisions, resulting from the integration of information from different actors; better acceptance of decisions, as broader agreement can be sought through people involvement; and the development of social capital, through intensive interaction and network-building. Some of these benefits occur as a product of learning.

3.2. Knowledge co-production and social learning

In our view, an approach is needed that is not only able to deal with complexity and uncertainty but is also able to integrate knowledge, both between many actors and between fields of knowledge. In other words, knowledge production needs to be consultative, deliberative and participatory. This can be referred to as knowledge co-production, mutual learning or transdisciplinarity (Russel *et al.*, 2008). Nowotny *et al.* (2001) define transdisciplinary knowledge production as problem-oriented, responsive and open to external knowledge producers, contextualised and system-based, adaptable, consultative and socially robust.

Suitable approaches to tackling wicked problems are being sought at various levels of transformative learning and participatory processes. Examples include the following:

- Scenario building in the Swiss water sector, which was organised as a process that enabled practitioners and researchers to clarify their respective propositions (Lienert *et al.*, 2006). The need for a shift from the current system's focus on technological optimisation to supporting strategic decision-making processes was realised.
- Makropoulos *et al.* (2008), who presented future scenarios appropriate for preparing robust, sustainable urban water management strategies. Their scenario planning approach was explorative in terms of its objective, i.e. stimulating creative thinking.
- The EU-project SWITCH (Sustainable Water Management Improves Tomorrow's Cities' Health), in which learning alliances have been successfully applied, consisting of structured platforms at different institutional levels, designed to break down barriers to both horizontal and vertical information sharing, thereby speeding up the uptake of innovations in urban water management (van der Steen & Howe, 2009).
- Dominguez *et al.* (2011), who advocated a complementary approach to strategic planning in the urban water sector – a discursive perspective that focuses on a structured, qualitative discussion of the objectives being pursued, the available alternatives and future uncertainties.
- Johnson *et al.* (2012), who showed that participatory scenario development (in a project on sustainable development in Minnesota) stimulates social learning. This supported collaborative sustainable development efforts.

In the approach taken in our futures research for the Dutch water sector, a strong emphasis is also put on knowledge co-production. The futures research referred to here is not based on the extrapolation of trends and postulation of predictions. It recognises the plurality of possible futures, emphasises the need to explore uncertainty and makes explicit what different stakeholders deem normatively preferable. Indeed, in situations where uncertainties in the knowledge base are high and conflicts about values and management objectives are substantial, social learning comes into play (Pahl-Wostl, 2007). Social learning has been recognised as a 'transitional and transformative process that can help create the kinds of systematic changes needed to meet the challenge of sustainability' (Wals, 2007). The emphasis is on co-learning, whereby individuals collectively develop new knowledge by making use of the diversity of perspectives and understanding at hand (Daniell *et al.*, 2010).

Table 2 summarises the method for developing a co-produced response strategy.

Although knowledge co-production is central to our approach for developing response strategies, the learning process should not be over-emphasised. It is essential to recognise the central role of uncertainty but it is equally important to differentiate between wild speculations and intelligent scenarios. The future should be treated as if it is open but not empty (van Asselt *et al.*, 2010). The 10 prominent developments we

Table 2. Method for developing response strategies.

Challenges	Response	Process	Result
Trends: • Complex • Uncertain • Diverse • Interconnected	Approaches: • Integrated • Adaptive • Participatory • Co-learning	Co-production: • Participatory backcasting • Social learning	Strategic response strategy: • Building-blocks • Knowledge and understanding • Learning alliance

present in this paper are understood and communicated from this perspective. The DWSI is a strategic learning alliance that was designed using the principles behind the methods summarised above.

4. Dutch water sector intelligence

DWSI is an horizon-scanning platform dealing with the future challenges of the Dutch water sector. DWSI was launched in 2008 by KWR Watercycle Research Institute and a team of pioneers from various drinking water companies and water boards. Futures researchers from KWR continuously examine and report on social, economic, political, technological, ecological and demographic trends in the context of the Dutch water sector. National studies are analysed and translated to the sectoral level in an integrated fashion. The futures research team also participates in various networks and attends conferences to tap into the most important developments. DWSI members are provided with concise trend alerts. The 10 prominent developments presented in this paper are based on these trend alerts.

The knowledge acquired through this research is used to design think-tank sessions with strategic thinkers and decision makers from the partner organisations and external experts who provide the strategists with new insights. The think-tank is the heart of DWSI: co-learning is facilitated by applying participatory backcasting and social learning principles (see also Segrave *et al*., 2011). Trend alerts are records of what the futures researchers have analysed and synthesised, and they provide water professionals with information. Through social learning in think-tanks, this information is developed into an integrated understanding in the minds of the water professionals: knowledge that they can then use for adaptive planning.

The possible impacts of future trends are balanced with the ambitions of the water sector and backcasted to what the organisations should and wish to do to prepare for the challenges. For example, participatory backcasting was applied in a working session on the water–food–energy nexus in cities. As well as representatives from the water sector, stakeholders from the energy and agriculture sector participated. Starting from a long-term future perspective in which a single utility organisation is responsible for water, energy and food services, backcasting was applied to jointly discuss the pathway to the envisaged situation. Participatory backcasting challenged the stakeholders to address issues such as who will take responsibility. Using a similar method, the learning alliance considered a 'what if' scenario by imagining a future situation in which an unknown virus has claimed numerous lives and experts believe that water is a possible transmission route. By imaginatively simulating the ensuing turn of events, participants explored the uncertainties and dilemmas and envisioned potential threats and opportunities for their organisations. Working collectively with representatives from diverse organisations enabled the participants to reflect on each others' assumptions and anticipate how they might interact in the given scenario, providing an insight into the roles of the different actors and highlighting any ambiguous areas.

The idea is to have discussions under different points of view that open up the spectrum of options. Through a process of collective exploration, members make the most of the diversity of knowledge and insights at hand, with representatives from all corners of the water sector. Carefully tailored group processes are used to reveal and test participants' assumptions and to facilitate the generation of alternatives to ascertain whether or not adaptation is needed for the changing circumstances. Examples of strategic response issues discussed in DWSI include the need for collective leadership in the water sector, ambition and vision for preserving biodiversity, collaboration in the water sector and with other sectors (such as energy and urban planning), a tailored communication strategy and open data, a cyclic innovation model, and dealing with risks of and preparation for pandemics. Participants leave the think-tank sessions with new conceptual building-blocks for response strategies for their individual organisations.

After 3 years, evaluation interviews were held with all DWSI members. The main outcome of the evaluation showed that participants had an appreciation for the social learning process, resulting in awareness of new perspectives and improved system thinking. Potential longer-term impacts regarding changes in the organisational practices and decision-making of the participating members has not yet been evaluated in detail. In the interviews, participants mentioned that feeding the insights gained back into their organisations is difficult, depending on the trends discussed. Trends are often characterised by either topical or geographical abstractness and/or long time frames, while many in the water sector have a strong ethos of doing practical things in the here and now. It often takes a fairly high degree of immersion in the trends that have been signalled to fully grasp their meaning and the potential consequences for the respective water organisations. It takes time and effort to translate and communicate the insights gained through the think-tank sessions back to each partner's own organisation. Finding such time has proven to be a challenge for the DWSI think-tank sessions' typical participants: strategic employees and/or members of boards of directors. Even so, as a real-life, enduring strategic learning alliance, DWSI has the potential to induce and catalyse higher-level institutional changes at the participating organisations over time. The fact that a group of thinkers is regularly working together to explore longer-term futures increases the institutional knowledge of the sector about potential contextual changes and the strategic options that the sector has in crafting a response. By investing in this knowledge, we aim to make the sector more resilient to change.

In addition, the DWSI results have already provided input for programming the research agenda of KWR. A new collective research programme has been put into place, addressing the challenges of the future by designing a multidisciplinary, thematic programme based on knowledge co-production in research.

5. Conclusion

The water sector is confronted with complex changes in technology, infrastructure and regulations, as well as economic and societal trends. By applying social learning principles, organisations in the Dutch water sector are preparing for future challenges. Such a participatory approach (which integrates knowledge among actors and between fields of knowledge) works well in dealing with problems like global climate change, security and the ageing population. Indeed, such future challenges are complex, uncertain, diverse and interconnected, and thus traditional strategic planning and knowledge production are no longer suited. Since we do not subscribe to the idea that the future can be known, it is difficult to provide measurable outcomes for our research. The 10 trends briefly highlighted here have been distilled through continuous research over the past 4 years, but the more significant and valuable result has been the immeasurable upgrading of this information into knowledge and understanding in the minds of key strategists and managers in the Dutch water sector. Through a purpose-designed learning alliance, participants have gained an awareness of diverse perspectives and improved skills in systems thinking. In this way, DWSI helps organisations to make intelligent strategic decisions based on informed, intersubjectively reviewed assumptions.

Acknowledgements

A major part of the outcomes presented in this paper was based on research financed by the Joint Research Programme of the Dutch Water Companies.

References

Brueck, T. M. (2005). Strategic planning in today's dynamic world. *Water Science & Technology 5*(2), 53–62.

Daniell, K. A., White, I., Ferrand, N., Ribarova, I. S., Coad, P., Rougier, J.-E., Hare, M., Jones, N. A., Popova, A., Rollin, D., Perez, P. & Burn, S. (2010). Co-engineering participatory water management processes: theory and insights from Australian and Bulgarian interventions. *Ecology and Society 15*(4), 11–48.

Dominguez, D., Truffer, B. & Gujer, W. (2011). Tackling uncertainties in infrastructure sectors through strategic planning: the contribution of discursive approaches in the urban water sector. *Water Policy 13*(3), 299–316.

European Environmental Agency (EEA) (2009). Water Resources Across Europe; Confronting Water Scarcity and Drought. EEA Report No 2/2009, EEA, Copenhagen.

Frijns, J., Middleton, R., Uijterlinde, C. & Wheale, G. (2012). Energy efficiency in the European water industry: learning from best practices. *Journal of Water and Climate Change 3*(1), 11–17.

Hegger, D. L. T., Spaargaren, G., van Vliet, B. J. M. & Frijns, J. (2011). Consumer-inclusive innovation strategies for the Dutch water supply sector: opportunities for more sustainable products and services. *NJAS Wageningen Journal of Life Sciences 58*(1–2), 49–56.

Hofman, J., Hofman-Caris, R., Nederlof, M., Frijns, J. & van Loosdrecht, M. (2011). Water and energy as inseparable twins for sustainable solutions. *Water Science & Technology 63*(1), 88–92.

Hooghe, L. & Marks, G. (2001). *Multi-Level Governance and European Integration*. Rowman & Littlefield, Lanham.

Johnson, K. A., Dana, G., Jordan, N. R., Draeger, K. J., Kapuscinski, A., Schmitt Olabisi, L. K. & Reich, P. B. (2012). Using participatory scenarios to stimulate social learning for collaborative sustainable development. *Ecology and Society 17*(2), 9.

Kok, K., van Vliet, M., Bärlund, I., Dubel, A. & Sendzimir, J. (2011). Combining participative backcasting and exploratory scenario development: experiences from the SCENES project. *Technological Forecasting & Social Change 78*(5), 835–861.

Lach, D., Rayner, S. & Ingram, H. (2005). Taming the waters: strategies to domesticate the wicked problems of water resource management. *International Journal of Water 3*(1), 1–17.

Lienert, J., Monstadt, J. & Truffer, B. (2006). Future scenarios for a sustainable water sector: a case study from Switzerland. *Environmental Science & Technology 40*(2), 436–442.

Makropoulos, C. K., Memon, F. A., Shriley-Smith, C. & Butler, D. (2008). Futures: an exploration of scenarios for sustainable urban water management. *Water Policy 10*(4), 345–373.

Nederlof, M. M., Frijns, J. & Groenendijk, M. (2010). Cradle to cradle drinking water production: sense or nonsense? IWA Water & Energy conference, Amsterdam, 10–12 November, IWA, Den Haag.

Nowotny, H., Scott, P. & Gibbons, M. (2001). *Re-thinking Science: Knowledge and the Public in an Age of Uncertainty*. Polity Press, Cambridge.

Pahl-Wostl, C. (2007). Transitions towards adaptive management of water facing climate and global change. *Water Resource Management 21*(1), 49–62.

Pahl-Wostl, C., Sendzimir, J., Jeffrey, P., Aerts, J., Berkamp, G. & Cross, K. (2007). Managing change toward adaptive water management through social learning. *Ecology and Society 12*(2), 30–38.

Palomo, I., Martín-López, B., López-Santiago, C. & Montes, C. (2011). Participatory scenario planning for protected areas management under the ecosystem services framework: the Doñana social-ecological system in Southwestern Spain. *Ecology and Society 16*(1), 23–56.

Pamminger, F. & Kenway, S. (2008). Urban metabolism: improving the sustainability of urban water systems. *Water 35*(1), 28–29.

Planbureau voor de Leefomgeving (PBL) (2011). *Scarcity in a Sea of Plenty? Global Resource Scarcities and Policies in the European Union and The Netherlands*. PBL publication number 500167001, PBL Netherlands Environmental Assessment Agency, The Hague.

Pierre, J. & Peters, B. G. (2000). *Governance, Politics and the State*. Macmillan, Basingstoke.

Quist, J., Thissen, W. & Vergragt, P. J. (2011). The impact and spin-off of participatory backcasting: from vision to niche. *Technological Forecasting and Social Change 78*(5), 883–897.

Rittel, H. W. J. & Webber, M. M. (1973). Dilemmas in a general theory of planning. *Policy Sciences 4*(2), 155–169.

Robinson, J., Burch, S., Talwar, S., O'Shea, M. & Walsh, M. (2011). Envisioning sustainability: recent progress in the use of participatory backcasting approaches for sustainability research. *Technological Forecasting and Social Change 78*(5), 756–768.

Russel, A. W., Wickson, F. & Carew, A. L. (2008). Transdisciplinarity: context, contradictions and capacity. *Futures 40*(5), 460–472.

Segrave, A., Büscher, C. & Frijns, J. (2011). Participatory futures research and social learning for integrated watershed management. In: *Environmental Security in Watersheds: The Sea of Azov. NATO Science for Peace and Security Series C: Environmental Security*. Lagutov, V. (ed.). Springer, Dordrecht, pp. 241–253.

Steel, C. (2008). *Hungry City: How Food Shapes our Lives*. Chatto & Windus, London.

Swart, R. J., Raskin, P. & Robinson, J. (2004). The problem of the future: sustainability science and scenario analysis. *Global Environmental Change 14*(2), 137–146.

Swierstra, T., Boenink, M., Walhout, B. & van Est, R. (2009). Converging technologies, shifting boundaries. *Journal of Nanoethics 3*(3), 213–216.

United Nations Environment Programme (UNEP) (2011). Decoupling natural resource use and environmental impacts from economic growth. A report of the working group on decoupling to the international resource panel, UNEP, Nairobi.

van Asselt, M. B. A., Faas, A., van der Molen, F. & Veenman, S. A. (eds) (2010). *Uit Zicht: Toekomstverkennen met Beleid*. Amsterdam University Press, Den Haag/Amsterdam.

van der Brugge, R. & de Graaf, R. (2010). Linking water policy innovation and urban renewal: the case of Rotterdam, the Netherlands. *Water Policy 12*(3), 381–400.

van der Steen, P. & Howe, C. (2009). Managing water in the city of the future: strategic planning and science. *Reviews in Environmental Science and Biotechnology 8*(2), 115–120.

van't Hof, C., van Est, R. & Daemen, F. (2011). *Check In/Check Out: The Public Space as an Internet of Things*. NAi Uitgevers, Rotterdam.

Veenswijk, M. (2005). *Organizing Innovation: New Approaches to Cultural Change and Intervention in Public Sector Organizations*. IOS Press, Amsterdam.

von Korff, Y., Daniell, K. A., Moellenkamp, S., Bots, P. & Bijlsma, R. M. (2012). Implementing participatory water management: recent advances in theory, practice, and evaluation. *Ecology and Society 17*(1), 30.

Wals, A. E. J. (ed.). (2007). *Social Learning: Towards a Sustainable World*. Wageningen Academic Publishers, Wageningen.

Wuijts, S., Büscher, C. H., Zijp, M. C., Verweij, W., Moermond, C. T. A., Roda Husman de, A. M., Tangena, B. H. & Hooijboer, A. (2011). *Toekomstverkenning drinkwatervoorziening in Nederland.* RIVM rapport 609716001/2011, RIVM National Institute for Public Health and the Environment, Bilthoven.

Received 27 February 2012; accepted in revised form 6 October 2012. Available online 7 December 2012