



Nanoremediation - your future business opportunities

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Introduction

This is the second of two free sessions intended to provide delegates with sufficient information to decide if nanoremediation and new techniques in nanoremediation is a viable activity for their organisation. It is particularly targeted at practitioners such as site owners/managers service providers (consultants contractors), and regulators.

Nanotechnologies could offer a step-change in remediation capabilities: treating persistent contaminants which have limited remediation alternatives, avoiding degradation-related intermediates and increasing the speed at which degradation or stabilisation can take place (Müller and Nowack 2010), among other potential benefits. In 2007 in Europe it was forecast that the 2010 world market for environmental nanotechnologies would be around \$6 billion (JRC Ispra 2007). In fact, adoption of nanoremediation has been slower, with fewer than 100 field scale applications, since the first field application in 2000. However, the recent emergence of nanoremediation as a commercially-deployed remediation technology in several EU countries, notably the Czech Republic and Germany indicates that it is timely for service providers and site owners or managers in Europe to reconsider its potential applications and the consequent implications for their business activities.

Since early 2014, the EU FP7 NanoRem project (www.nanorem.eu) has been carrying out an intensive development and optimisation programme for different nanoparticles (NPs), along with analysis and testing methods, investigations of fate and transport of the NPs and their environmental impact. NanoRem is a €14 million international collaborative project with 28 Partners from 12 EU countries, and an international Project Advisory Group (PAG)

providing linkages to the USA and Asia. It is a major initiative, which will support the effective deployment of nanoremediation technologies in Europe. As part of its work it offers these two sessions to provide key information for organisations considering diversifying into nanoremediation, or already beginning that process.

The **first** free session focuses on providing a practical grounding in nanoremediation theory and practice with particular reference to applied examples in the field.

The **second** free session focuses on providing business and strategic intelligence for delegates with interests in using nanoremediation at their sites or developing nanoremediation activities at their organisations.

Stephan Bartke, UFZ, Germany: What will drive the EU nanoremediation market till 2025 – assessment of factors determining opportunities and challenges for the take-up of nanoremediation (15 minutes).

This presentation will review stakeholder meeting and focus group information collected by NanoRem over 2014/2015 on factors determining market developments. The intention is to provide an informative but not prescriptive talk. Part of the strategic and business intelligence provided will be from self-learning as the session delegates interact with each other in a structured way in small groups.

Various external determinants from economy, technology development, politics and society affect the property market in general and the industry for contaminated land remediation in particular. In order to develop an exploitation strategy that considers the medium to longer term potential market development for nZVI, any analysis has to deal with an uncertain future. The factors (i.e. drivers and uncertainties related to driver development) that foster or inhibit the evolution of the market need to be better understood. It is unclear how the factors likely to influence the nanoremediation market development are linked, and how they are likely to develop in the future. It is challenging, therefore, to make any straightforward predictions regarding the emerging nanoremediation market. As a result, traditional supply and demand modelling is unsuitable. A simple use of neo-classic economics' theory will fail to reveal and quantify the role that nano-remediation options could unfold under different future market conditions, because there are severe caveats regarding standard assumptions made in such traditional market assessments. A scenario approach will therefore be used to help forecast potential market developments. The outcomes are utilisable for: "real-world" business development, deducing strategies for market activities; informing policy development, identifying governance options for market expansion; and/or informing regulatory authorities, highlighting the potential for nanoremediation.

The Scenario Approach

Scenarios can be defined as "internally consistent stories about ways that a specific system might evolve in the future" (March *et al.* 2012, 127). Scenario analysis builds on both i) a system thinking approach, i.e. it acknowledging that actors are in a complex network of manipulable and uncontrollable drivers, which are connected to each other; and ii) the ability to think in multiple futures, i.e. actors do not reduce strategic thinking to merely one precise anticipated future, instead, they insure alternative futures are generated and applied in strategic management (Gausemeier *et al.* 1998).

In essence, a scenario-based approach to understanding possible market trends uses available evidence and stakeholder participation to develop a number of narratives describing the potential evolutionary outcomes of a specific market system. Hence, this approach has been applied in order to help determine:

- (i) What the factors (drivers and uncertainties) are in the nanoremediation market-system.
- (ii) What the extent of the factors' impacts is.
- (iii) How the factors interdepend.

Scenario design and analysis differ, but usually a stepwise approach is taken. In NanoRem, the following procedure was selected:

- 1) Conducting a present situation analysis to establish the baseline for scenario development and a framework for factor identification.
- 2) Filtering and systematising factors that drive or inhibit market development. Establishing key determinants.
- 3) Projection of key factors' developments and producing consistent stories about ways the system might evolve in the future. Identification of multiple alternative development trajectories is possible.
- 4) Deciding on planning-oriented exploitation strategies, which may be responsive or proactive. Development of governance recommendations.

Scenarios can be established through participatory or through individual, often analytically based research (van Notten et al., 2003; Alcamo 2008). When accomplished in a stakeholder involving manner, scenario development may serve as an exercise in 'anticipatory' or 'social' learning. NanoRem applied a participatory approach, as this is said to better being able to capture the high diversity of drivers affecting the evolution of a system into the future (March et al. 2012). Involving experts will ensure the relevance of the work for practical stakeholder needs, decision support as well as for recommendations on exploitation strategies.

Figure 1 below, gives an overview of the the work conducted so far as part of a scenario approach, and ongoing work. The steps are discussed further in the following sections. The overall approach is discussed in more detail in Bardos *et al.* 2015 and the workshop is reported in further detail in Tomkiv *et al.* 2015

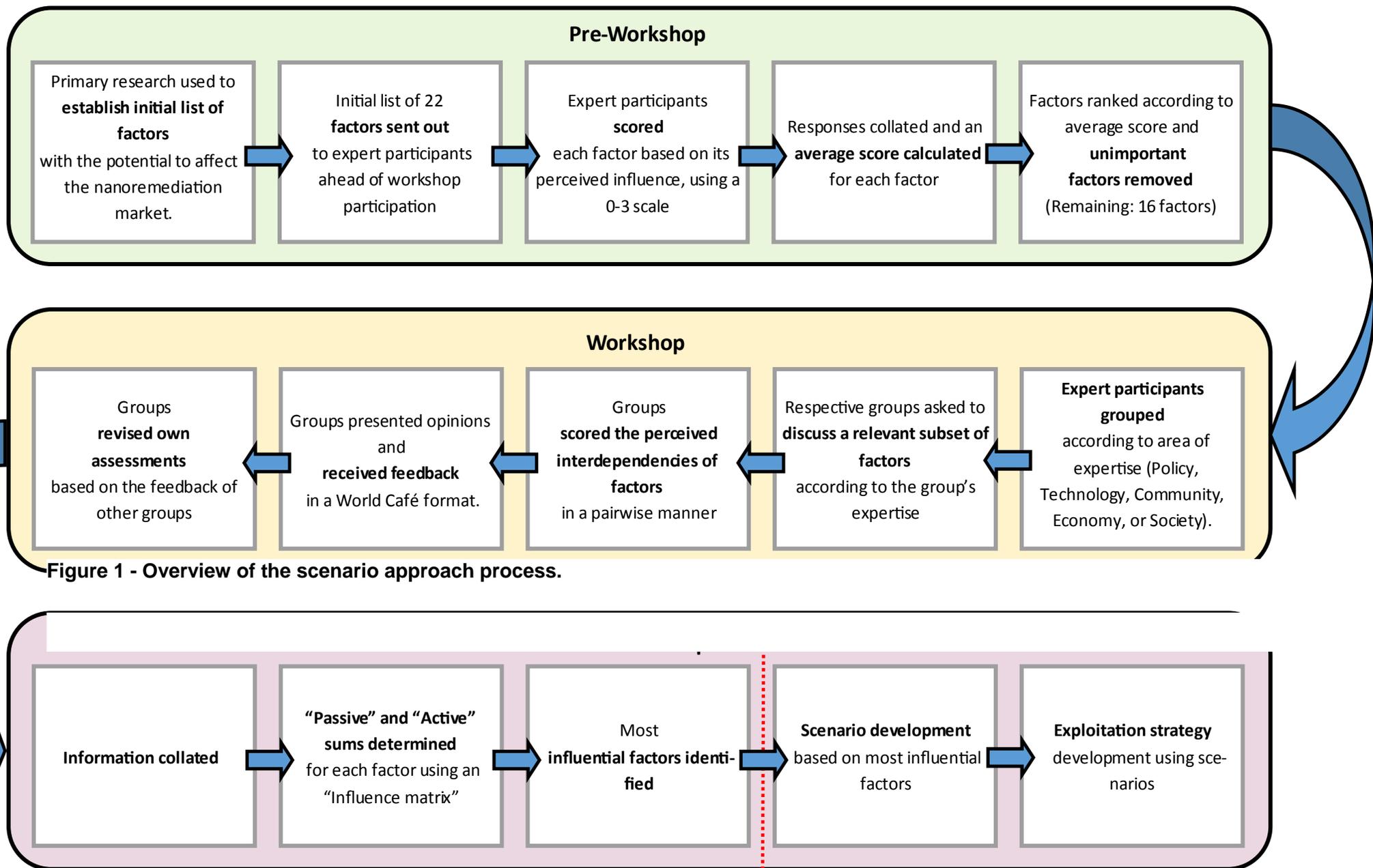


Figure 1 - Overview of the scenario approach process.

Establishing the Baseline for Scenario Development

To fulfil step one of the scenario development approach, a baseline understanding of the nanoremediation market and the set of factors with the potential to influence the future development of the nanoremediation market was established. This was achieved via key-informant interviews and literature analysis, taking into account the market *status quo* and risk-benefit appraisal (cf. Bardos et al. 2014). This preliminary research helped establish a variety of external determinants from economy, technology development, politics and society that may affect:

- The property market in general;
- The industry for contaminated land remediation broadly, and;
- The potential evolution of nanoremediation in particular.

Expert engagement (key informant interviews and expert discussion) was utilised to establish the most worthwhile timeframe for the scenario approach. A consensus was reached that evolution of the market up to 2025 was the most appropriate scope. It was felt that a very long-term assessment would be impossible due to the significance of unknown and uncertain factors. After several iterations with expert involvement, a condensed list of 22 potentially influencing factors was established.

Systematising Market Development Factors

To aid step two of the scenario design process, a “Market Opportunities” session was included in the Sustainability and Markets workshop (cf. Tomkiv et al. 2015). The Oslo event was a participatory approach to conclude on the systematic interdependencies and importance of the factors in order to capture through engagement with the participants with their different backgrounds the high diversity of drivers and inhibitors affecting the market system.

The 22 factors determined in the preliminary research stage were grouped into different categories (policy, economy, society, communication, technology and megatrends). The use of categories helped to align the factors with appropriate expertise for later discussions. In order to further condense the list of factors and remove less important factors, the list was sent to the workshop participants in advance of the workshop. Participants were asked to provide feedback on how important they perceived each factor to be for the development of the EU nanoremediation market from present to 2025. Participants scored each factor according to the following scale:

- (0) = Negligible relevance – the factor is not an important driver or inhibitor;
- (1) = Minor relevance – the factor might have a limited but not so important effect;
- (2) = Considerable relevance – the factor is likely to have a notable (indirect) effect;
- (3) = Key relevance – this factor is most certainly among those of utmost importance to push or pull the nanoremediation market development.

The responses (20 respondents) were collated and an average score (the arithmetic mean as the sum of the scores collected from all the respondents, divided by the number of the respondents) was calculated for each factor. The results are shown in Table 1 below, in descending order of obtained scores.

Table 1 – Preliminary factors and their perceived importance with regards to influencing nanoremediation market development in the EU up to 2025

<i>Factor</i>	<i>Score</i>	<i>Category</i>
Most important factors (≥2.00):		
Innovation on treatment of known contaminants with NPs	2.48	Technology
Regulation of nanoparticles	2.45	Policy
Validated information on NP application potential	2.40	Communication
Costs of competing technologies	2.35	Economy
Standardization for nanoparticles	2.20	Policy
Innovations along NPs production chain	2.18	Technology
Environment (especially soil) protection policies	2.10	Policy
Synergies with other technologies	2.05	Technology
Public stakeholder dialogue	2.00	Communication
Less important factors (>1.50 and <2.00)		
NP treatment of emerging contaminants	1.95	Technology
Public perception of NPs in general	1.93	Society
Science-Policy-Interface	1.93	Communication
Technology and research policies	1.75	Policy
Growing number of nanoparticles suppliers	1.73	Economy
Real estate market development	1.68	Economy
Innovation attitude	1.60	Society
Environmental awareness	1.55	Society
Minor relevant factors (≤1.50)		
EU economic development	1.50	Economy
Globalisation	1.20	Megatrend
Industrial and military land use	1.00	Society
Climate change	0.70	Megatrend
Demographic change	0.60	Megatrend

The scorings indicate that several factors influence the market's development. Some of the scorings, e.g. the ability to treat emerging contaminants with NPs, are surprising and may indicate either bias or epistemic issues in the mind of the responders. As no factor had a scoring > 2.50, it was concluded that no factor is likely to singlehandedly "push" or "pull" nanoremediation market development.

In order to create scenarios, the interdependencies of the factors determined to be important needed to be better understood. Stakeholders were provided with the factors in Table 1 including short descriptions of each factor. During the workshop, stakeholders were asked to provide opinions, comments and suggestions about the factors and were also asked to identify and discuss the interrelations of the factors. In order to do this, stakeholders were divided into smaller groups based on their field of expertise. The groups formed were Regulators / Policy makers, Technology, Communication, Economy and Society. Participants in the respective groups were asked to discuss the influence of three or four factors of their respective expert domain on the full list of factors identified to be of importance.

For each group a poster with an empty influence matrix was provided showing a short list of factors from the respective field of a group's expertise in the rows on the vertical axis and the full list of factors in the columns on the horizontal axis. **Figure 2** illustrates the influence matrix's outline.

Influence matrix														
Question: »How strong is the impact of factor A (row) on factor B (column)?«														
scale:														
0 = no impact														
1 = weak and delayed impact														
2 = medium impact														
3 = strong and direct impact														
		activity (sum of rows): How strong is the impact of a factor on all other factors?												
		1	2	3	4	5	6	7	8	9	35	36	active sum	
1 buying habits			2	2	3	-	1	2	2	1			13	
2 cashless money transfer		1		-	-	-	-	3	2	3			17	
3 size of purchasing points		-	1		2	-	1	-	3	3			13	
4 home-shopping		-	2	1		-	-	3					10	
5 buying power		3	2	-	1		-					2	15	
6 hours of opening		2	2	2	3	-							13	
7 use of credit cards		-	1	-	-	-			1	1			10	
8 use of consumer cards		-	1	-	-	-	-	2		3			6	
⋮														
35 system of values		3	-	-	1	-	-	-	-	-		2	26	
36 growth rate		2	-	-	-	3	1	-	-	-			19	
passive sum		30	41	13	31	14	7	25	17	24		10	14	

Figure 2 - Interaction matrix illustration (Gausemeier et al., 1998, p. 119)

The participants in a first phase were asked to review and provide opinions, comments and suggestions about the collected factors in the rows. Next, they were asked to identify and discuss the interrelations of the development of each of their factors in the lines on the full list of factors, i.e. to discuss pairwise the influence of development of a factor from the vertical axis on the development of a factor from the horizontal axis. For the assessment, again a scoring was re-requested (as indicated in **Figure 2**, too): Considering the European Union in 2025, the impact of the development of the factor in the row on the development of the factor in each column was gauged using the scale:

- (0) = No impact;
- (1) = Weak / delayed impact;
- (2) = Medium impact;
- (3) = Strong / direct impact.

At the end of this phase, each group had filled in their part of the influence matrix. After the work-shop it was possible to add up the rows and to obtain a full matrix containing all factors in the rows and columns – however, this was not done at the Oslo event, as the key objective here was to best substantiate the assessments within the matrix. Therefore, in a subsequent phase of the event, taking up the World Café™ format, the participants were invited to discuss one by one the results of the other groups. Facilitators guided these discussions from the identification to the review of the linkages of factors. At the end of the phase, the participant returned to their “home table” and revisited their assessments based on the feedbacks collected from the other groups. At the end of the Session, the annotated posters and notes of facilitators were collected and interpreted.

After the workshop, the information collected from the group sessions was analysed and the factors that are more “active” in influencing other factors were identified, as well as those that are more driven by the active ones. These relationships are expressed by the “active sum” and “passive sum” as indicated in **Figure 2** above and in Table 2, below. Table 2 lists the five most active factors from those recorded in order of their activity (i.e. how influential a factor is relative to other factors).

Table 2 - Interrelatedness of factors determining the development of the nanoremediation market

Factor	Active sum*	Passive sum*
Science-Policy-Interface	38	26
Validated information on NP application potential	36	21
Environment (especially soil) protection policies	25	17
Public stakeholder dialogue	25	20
Synergies with technologies	24	20

*Active and Passive sums had a maximum potential value of 48. The closer the active sum for a factor is to 48, the more influential that factor is. Conversely if the passive sum for a factor is close to 48, it is likely to be highly influenced by changes in other factors.

Projection of Factor Development and Establishing Consistent Scenarios

As part of ongoing work, a series of expert engagement activities is underway. In March 2015, NanoRem conducted a first focus group meeting and expert workshop in Berlin, Germany, in order to discuss the establishment of consistent scenarios. The participants were provided with an overview of the interim results of the scenario analysis work. They were shown that the two most “active” of the key factors were identified as: “Science-Policy-Interface” and “Validated information on NP application potential” (see **Table 2**) and hence, these factors are likely to be crucial in determining the development of the nanoremediation market system. These two factors were suggested for the development of framing elements for a conceptual scheme for scenario states. The participants discussed the meaning of these factors and tentatively defined them as follows:

- Science-Policy-Interface is part of a broader ‘Dialogue’, which is the process by which stakeholder groups (in particular those from science, policy and regulation) have informal/formal discussions, consultations and other forms of engagement in order to ascertain the potential application of nanoremediation (in general or in specific cases).
- Validated information on NP application potential is an ‘Information’ dimension, which describes the quality of available information for decision-making. Information can range from a level of great uncertainty with regards to the potential developments of the market and the set of factors driving the market, to a situation where information about nanoremediation is readily available, well tested, and broadly accepted (i.e. “validated”). “Validated information” gives credence to a decision regarding its applicability.

These dimensions form the conceptual scheme for the scenario states of the nanoremediation market. These scenario states show four potential future states for the market, see Figure 3 below, (going clock-wise in each quadrant of the matrix):

- I. Validated information is broadly available AND there is comprehensive dialogue between stakeholders, in particular those from science, policy and regulation.
- II. Validated information is lacking and uncertainty is still significant BUT there is comprehensive dialogue between stakeholders, in particular those from science, policy and regulation.
- III. Validated information is lacking and uncertainty is still significant AND there is no or only minimum dialogue between stakeholders, in particular those from science, policy and regulation.

- IV. Validated information is broadly available BUT there is no or only minimum dialogue between stakeholders, in particular those from science, policy and regulation.

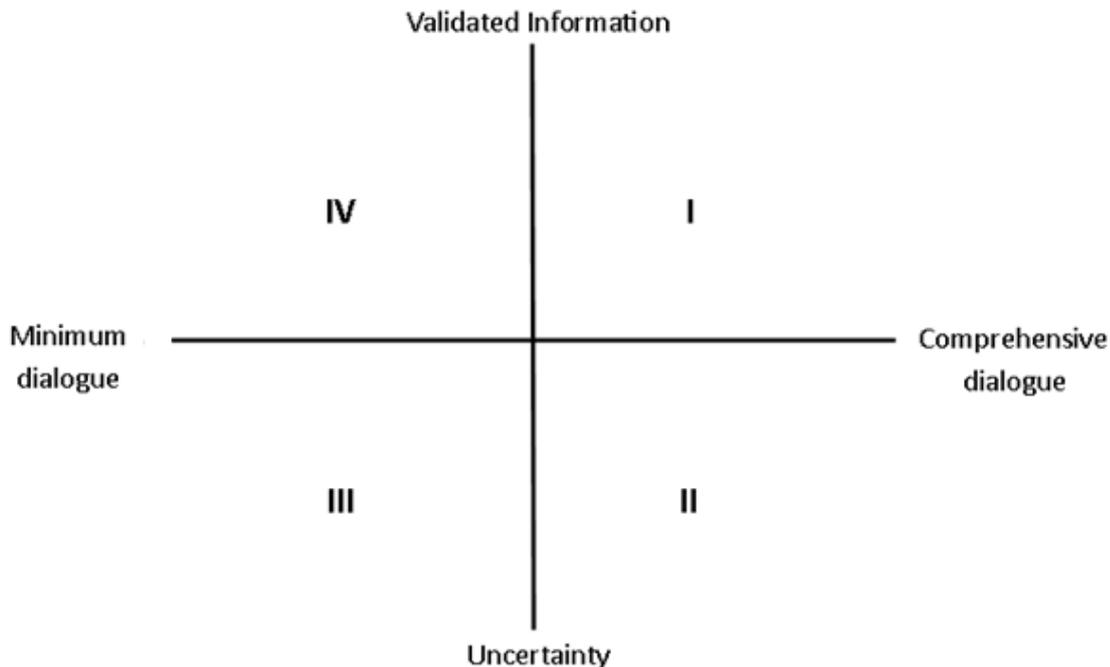


Figure 3 Conceptual Scheme for Scenario States

The final steps of the scenario analysis will be the discussion of the key factors' developments within the different scenario states, and based on these, the deduction of scenario storylines. These discussions will finally inform the conclusion of recommendations for the exploitation strategy.

The Scenario approach will continue to be expanded, with scenario development continuing over Year 3 of the NanoRem project. Further expert engagement in focus groups and workshops has been planned in order to discuss the scenario scheme and future market states that reflect the interactions identified in the Oslo workshop and specify directions of factor development under the potential market states. The scenario storylines concluded from these activities will be used to derive conclusions on the medium to longer term exploitation opportunities and recommendations for entrepreneurs and policymakers.

Nicola Harries, CL:AIRE, UK; Elsa Limasset, BRGM, France; Stephan Bartke, UFZ, Germany; Paul Bardos, r3 environmental technology ltd, UK. Discussion of possible market trends and opportunities (60 minutes)

Discussion in groups, each with a NanoRem facilitator to provide a chance for active discussion and exchange of ideas about market prospects, drivers and recommendations we can conclude on the day. A short report of findings will be provided on <http://www.nanorem.eu/news.aspx> by the end of August 2015.

The discussion addresses the following questions in particular

1. How are things changing / likely to change
2. What is the most critical information to achieve positive shifts in the uptake of nanoremediation
3. How are the factors presented likely to influence the various organisations and people taking part in the Café.

Discussions will use the World Cafe™ discussion format (http://en.wikipedia.org/wiki/The_World_Caf%C3%A9) and will be followed by a plenary session where each group can report back and ideas can be exchanged

Paul Bardos, r3 environmental technology ltd, UK. Wrap Up and Clinic Offer (10 minutes)

A NanoRem brochure “Nanoremediation: what’s in it for me?” will be provided to participants. This will include an enquiry form which can be completed and handed back to the session organisers on the day. The brochure and form will also be available as a link on www.nanorem.eu. The enquiry form offers the chance for delegates to find out more about the NanoRem project, but also to ask specific questions about their own nanoremediation interests which the consortium will endeavour to answer in the weeks following AquaConsoil.

Note: Delegates will be provided with a NanoRem web link for take home materials from special session presentations that they can use within their own organisations to support further decision-making

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