



# Sources of Uncertainty in Formulation of the Cognitive Scenarios for Development of Water Management

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**Abstract:** Uncertainty is a frequent obstacle in decision making process, therefore understanding its sources might facilitate this process and increase its effectiveness. The objective of the paper is to identify the sources of uncertainty in planning in water management, which have been revealed and identified by carrying out the process of developing cognitive scenarios in the Klimat project (POIG.01.03.01-14-011/08). The paper discusses scenarios for development of water management and the development process thereof in the Klimat project. Selection of literature is presented, showcasing other projects in which scenario analyses of this type from around the world have been performed. A method of formulating development scenarios in water economy is presented, along with its results, which reveal the sources of uncertainties in water management planning.

**Keywords:** scenario, water, management, expert

**JEL codes:** Q25, Q54, O21

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## 1. Introduction

Planning and management in water economy, despite improved techniques and tools, is still burdened with a high degree of uncertainty and risk. This is primarily caused by complexity of these processes and the necessity to take into account not only the aspects of natural environment,

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but also social and economic issues. Uncertainty is a state in which choosing a specific action may entail various consequences, while probability of their occurrence remains unknown. The decision maker does not know the state of the world, and therefore the description of consequences for each action. This issue affects many areas of life, particularly in the decision making process, where the consequences cannot be unambiguously predicted. Uncertainty is a notion used in many scientific fields, including statistics, engineering sciences and economy. Measuring uncertainty is based upon a set of possible present and future states together with corresponding probabilities of their occurrence. In metrology, uncertainty, or measurement margin of error, are determined by the scope surrounding the true value. Mathematical quantification of uncertainty is used in modelling for limiting it in specific applications.

Uncertainty is reflected in water management. Uncertainty also pertains to studies on the key factors regarding preparation for climate change and implementation of Integrated Water Resources Management (IWRM). These include proper management of water resources, which should be based upon broad, grounded knowledge, active participation of the public, political will and cooperation of all the parties participating in the process among others (Maciejewski, Walczykiewicz, 2015) Water resources are strictly related to global factors of change, such as climate, spatial planning and population, with its growing needs. In strategic planning, variant scenarios for development of water management are gaining in importance. Scenarios for development of water management are visions for the future, complete with description of the impact of external factors on the analysed water system. Principally, scenarios can be divided into two types depending on the purpose of their development - these are cognitive and normative scenarios. Cognitive scenarios are developed on the basis of identifying, as accurately as possible, the future form of the most important factors affecting the development of the situation; they are used to determine the probable state of the world. Normative scenarios, on the other hand, lead to indicating as to how can a desired effect be achieved in the upcoming time (Müller, 2008). The basis for their construction are desired, but unlike in the first case, not objective expectations regarding the future. Normative scenarios allow for construction of a series of actions, which together form the future policy.

The objective of the paper is to identify the sources of uncertainty in planning in water management, which have been revealed by carrying out the process of developing cognitive scenarios in the Klimat project (POIG.01.03.01-14-011/08). The paper presents scenarios for

## SOURCES OF UNCERTAINTY IN FORMULATION OF THE COGNITIVE SCENARIOS FOR DEVELOPMENT OF WATER MANAGEMENT

development of water management and the development process thereof in the Klimat project, which has been the first project in which scenarios regarding water management on a scale of Poland have been formulated and analysed. Literature selection showcases other projects in the world in which scenario analyses for this type have been carried out and indicates that the scenarios developed for Poland are linked with analyses carried out on global scale. A method of formulating development scenarios in water economy is presented, along with its results, which reveal the sources of uncertainty in water management planning.

### **2. Scenarios for development of water management in KLIMAT project**

Many visions for the world development have been created, including also an analysis of consequences for the future condition of the environment. These reports had been developed for the needs of governments of specific countries and for international organisations. Some of them contain direct references to the issues of water management. Some of them are presented below.

#### **Global Trends 2025: A Transformed World Report**

Global Trends 2025: A Transformed World Report (2008) has been developed by the American National Intelligence Council. It discusses the factors, which will shape the main international trends and affect possible conflicts by the year 2025. Because of the fact that in the next 20 years, the world population will increase by around 1.2 billion people, demand for food will increase by 50%. Due to rapid development of cities, the situation regarding constant access to clean, drinking water will deteriorate.

The report points out that it is necessary to develop new technologies, which would provide "real alternatives to natural fuels" and help overcome future shortages of food and drinking water.

#### **Millennium Ecosystem Assessment**

During the Millennium Ecosystem Assessment (MEA, 2005), the scenarios were developed in a global system and some of them were prepared for selected European countries. All the scenario sets are based on the four main ones, which were determined to be: "Global Orchestration", "Order

from Strengh”, “Adapting Mosaic” and “TechnoGarden”. They are shortly described below revealing the main assumptions.

“Global Orchestration” is a scenario presenting a society focused on market and global trade, where liberalisation in economy is generally accepted. This scenario is characterised by the highest economic growth, but also the lowest population around 2050.

“Order from Strengh” presents a regionalised and heavily fragmented world, focused on security and protection, where little attention is paid to public well-being. This scenario is characterised by the lowest economic development and the highest population level.

“Adapting Mosaic” is characterised by concentration of political and economic activity on systems based on drainage basin areas. Management of local ecosystems is particularly significant in this scenario. Economic development is initially low, but it accelerates with time.

“TechnoGarden” is a world based entirely on modern, advanced technologies fostering protection of the environment. This allows for a relatively big economic growth. Population reaches medium levels compared to the other scenarios around the year 2050.

## **Visions / MedAction**

The overview of the Visions / MedAction initiative includes scenarios for Europe, Mediterranean states, local case studies and general European visions. Three main European scenarios have been included in it: “Big is beautiful”, “Big is beautiful?” and “Knowledge is King”.

In general, these scenarios, similarly to the other presented in this paper examples, included global and comprehensive analyses (visions of the future world) constructed upon two basic axes of uncertainty related to globalisation vs. regionalisation of the world in the future and pro-active vs. reactive societal attitudes. Unfortunately, the mentioned Visions / MedAction scenarios do not pertain directly to water management, as it is included in the following scenario sets:

- World Water Vision (WWV),
- European Environment Agency European Environment Outlook (EEO),
- Global Water Outlook (GWO).

These studies, however, are not as complete in terms of analyses of driving forces as the global scenarios.

## SOURCES OF UNCERTAINTY IN FORMULATION OF THE COGNITIVE SCENARIOS FOR DEVELOPMENT OF WATER MANAGEMENT

In this context the European Outlook on Water Use report (Floerke, Alcamo, 2004), developed on a basis of a contract with the European Environment Agency, is particularly important for the European water management. The report contains scenarios for future water usage in the European countries in the 2030 perspective.

### **Global Environment Outlook (GEO4, GEO5)**

In GEO4 (2007) and GEO-5 (2012), four scenarios have been developed – “Market First”, “Policy First”, “Security First” and “Sustainability First”. (UNDP, 2007; UNDP, 2012) These scenarios have been further developed with a focus on water resources management in the Scenes Project (Water Scenarios for Europe and Neighbouring States) (Alcamo, 2009; Kok et al., 2010) also for the of Narew river basin in Poland (Gielczewski et al., 2011). They received the names highlighting their main assumptions: “Economy First”, “Policy Rules”, “Fortress Europe” and “Sustainability Eventually”. They also served for planning the future of water on local and regional level in Ukraine (Zhovtonog et al., 2011). The Scenes project scenarios could be considered as most relevant and comprehensive global scenarios related to the water sector.

More on the types of scenarios and the geneses on their development can be found in the publications of Hunt et al. (2011) and Dubel (2016).

The developed scenarios have enabled analysing sensitivity and planning of appropriate adaptation to possible climate changes. In order to implement adaptation goals and achieve the Integrated Water Resource Management (IWRM) objectives also in the future, it is necessary that water administration and water system users are involved in limiting the uncertainty in parallel. It should be stressed that the importance of good practice in IWRM increases especially in a situation of advancement in development of water infrastructure. In other words, the requirements regarding the quality of management rise proportionately to the number of water management technical structures. These practices, implemented with participation of the water system users community appear to be more appropriate and according with the idea of IWRM.

In the Klimat project<sup>1</sup>, developed by the Institute of Meteorology and Water Management National Research Institute (IMGW PIB), the adopted framework for considerations were three

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<sup>1</sup> “Impact of the climate change on environment, economy and society (changes, impacts, ways of limitation, proposals for science, engineering in practice and economy planning) “ realized in the Institute of Meteorology and

emission scenarios developed by IPCC, with code names adopted in the Special Report of Emission Scenarios: A1B, A2 and B1. In this paper, they are named: A1B - market, A2 - regional, B1 - sustainable. Their brief description is presented below:

- Scenario A1B (high economic growth - globally) within the Klimat project followed the assumptions of the globally developed “Market First” scenarios. It assumes a very rapid economic growth. The population grows until year 2050, and then it decreases. New and efficient (in particular water- and energy- saving) technologies are implemented quickly. The increased economic cooperation and migration of population bring about equalization of civilization level and of income levels in different regions of the world. This option assumes a balanced scheme of power systems, created as a result of equal development of all ways of generating power.
- Scenario A2 (economic growth - regionally) for the purposes of the Klimat project was described as the „regional” scenario. In this option it was assumed that: development is driven by economic growth, gap between rich and poor countries increases, population is growing rapidly as well as there is lack of commitment to environmental issues and the slowest technological growth compared to other scenarios. The characteristic feature of this scenario is the lack of progress in the field of alternative sources of energy and coal remains the basic source of energy for Poland.
- Scenario B1 (sustainable development - globally) for the purposes of the Klimat project was described as the „sustainable” scenario. In this option one assumes the following: high level of ecological and social awareness, departure from the purely economic consumer attitude, in favour of sustainable development. Great significance is attached to the sustainability by governments, business, media and the lay people. One consciously and intensively invests in technology, efficacy, and environmental protection. Development concentrates on finding global solutions to problems of sustainable development.

At IMGW PIB, the global IPCC scenarios have been analysed and adapted for Poland, constituting a socio-economic assumptions for scenarios for development of water management in the 2030 perspective. The assumptions developed for each scenario by the team of experts in-house have been verified and complemented based on results from a poll research and discussions with experts

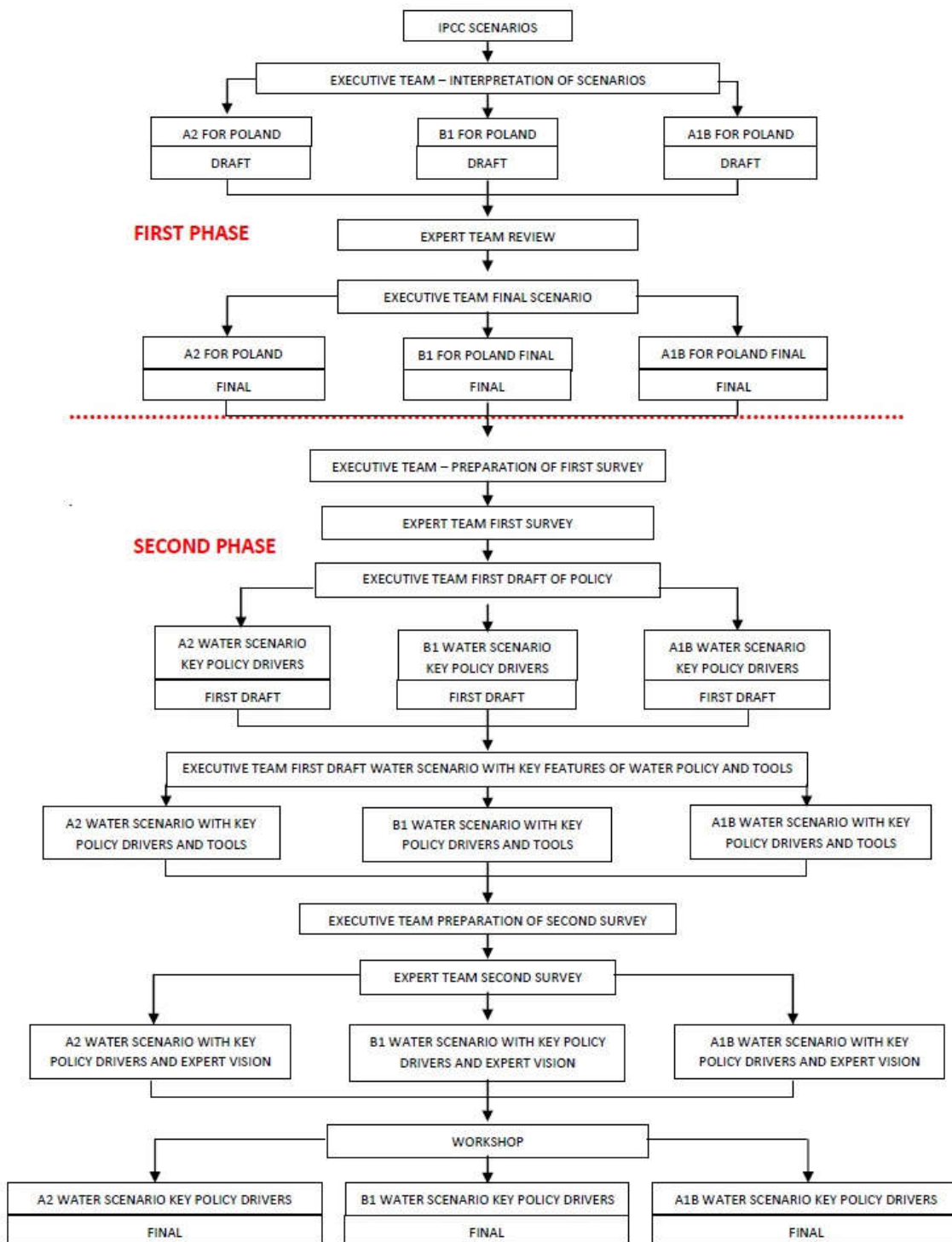
SOURCES OF UNCERTAINTY IN FORMULATION OF THE COGNITIVE SCENARIOS  
FOR DEVELOPMENT OF WATER MANAGEMENT

possessing multi-sectorial knowledge. The final scenario vision and assumptions were based on the combination of the vision of the executive team and the suggestions of the team of external experts. Executive team consisted of IMWM experts who implement the Klimat project. Whereas, the expert team consisted of specialists studying the issue of water management and other sectors working at universities, water administration and the Polish Academy of Science, whom the executive team invited to collaborate in the development of scenarios. Based on the results of climate models, assumptions, regarding the probable climate changes in Poland by the end of the century, have been made in this process of water management scenarios development. It was assumed that, by 2030, there will be no significant changes in the size of water resources compared to the present state. In a longer perspective, a significant increase in temperature and shifts in temporal distribution of precipitation are possible, which would result in a change in the flows regime. Increased frequency of extreme phenomena (floods, droughts) is probable. Assumptions regarding climate changes take into account a further time perspective than considerations for water management scenarios. This allows including in these scenarios adaptation actions preceding climate changes.

The above-mentioned assumptions regarding the socio-economic environment and future climate changes, constituted the basis for drawing conclusions regarding the directions of development of the water management in Poland.

The scenario development process in the project is illustrated by the diagram below (Fig.1).

**Figure 1: Scenario development process in the Klimat project**



Source: Authors own elaboration



### **3. Poll research in the Klimat project for formulating scenarios for development of water management**

Pool research in the Klimat project for formulating scenarios for development of water management was conducted in Cracow from 20<sup>th</sup> July to 16<sup>th</sup> November 2009. (Dubel A., 2009). Research on risk in management taking into account the sociological and economic context are particularly important, because currently, water management significantly extends beyond technical considerations and encompasses social and economic development as well as prognostics in these areas. Research in this group pertained to factors affecting good management, among others. Good management was defined as a combination of the following types of factors:

- those accounting for water resources and water system-dependent ecosystems,
- legal - responsible for allocation of resources,
- technical - connected with the functioning water infrastructure,
- effective hazard management.

The pillars of good management are:

- predictable, open and transparent water policy,
- professional (in accordance with the public interest) activity of the services responsible for water management,
- strong public support and participation in the management process.

The poll research consisted of two groups of questions. The first one, titled "Policies and instrument resulting thereof", included general questions regarding the goals, with which water economy will be presented in each emission scenario (socio-economic development scenario) as well as questions regarding the tools for achieving these goals. The second group, known as "Features of water management", comprised of more detailed questions regarding the state of water economy anticipated for each scenario. These included water usage, condition of the environment, technical infrastructure and level of protection against extreme phenomena (drought, flood), which are de facto effects of using the tools for implementation of policies defined in the first part of the poll or the impact of the environment on the water economy. Each of the questions was preceded by a short introduction.

The questions had been formulated taking into account factors and pillars of good management; some of the questions contained sub-questions. The main questions were formulated as follows:

1. Will the importance of water policy in Poland change?
2. Which of the rules of Integrated Water Resources Management will be contested and consequently not observed?
3. Will the approach towards flood and drought hazards based on risk management become generally accepted?
4. How important will each area of water management be in strategic planning?
5. What groups of instruments will be preferred in water management?
6. What instruments will play a significant role in water management?
7. What will the individual water consumption look like? Per capita, in relation to GDP, for each user category?
8. How will the water demand change in Poland for each user category?
9. Will the quality of water in the water systems improve?
10. What will the investments regarding construction of water management technical structures look like compared to the current situation?
11. Will there be changes in design and development of new water management structures and modernisation of the existing ones that would be beneficial for the environment and the landscapes?
12. In which areas will there be a significant increase in the security/risk culture regarding natural hazards, especially floods and droughts?

In total 27 respondents participated in the poll, including: 13 people representing the water management administration, and 14 participants from universities and research institutes (including 4 from IMGW PIB).

All the questions were closed questions, with the answers being selected from a list. Formally, the questions can be divided into two types. In the first case, the respondents answered "yes" or "no", which gave an answer to the question, which option is preferred. At least 2/3 of the respondents had to give the same answer for the result to be deemed unambiguous. The second type of questions pertained to either determining the trends in the changes of various values, or the hierarchy of various issues. In this case, the respondents selected one of 5 answers, which could be ordered (e.g. from "insignificant" to "very significant" or from "will decrease significantly" to "will increase significantly"), and translated into numeric values for the analysis. In this case, the result was a median of the respondents' answers. The result was deemed to be unambiguous if answers

SOURCES OF UNCERTAINTY IN FORMULATION OF THE COGNITIVE SCENARIOS  
FOR DEVELOPMENT OF WATER MANAGEMENT

of at least 2/3 of the respondents were present in the section the length of half of the variable area and the centre equal to the median. For the adopted assumption, the criterion of unambiguity for a 5-degree scale is as follows:

$$\frac{\text{number-of-votes}_{\text{median}} + 0.75 * (\text{number-of-votes}_{\text{median}-1} + \text{number-of-votes}_{\text{median}+1})}{\text{number-of-votes}} \geq 0.667*$$

Out of 78 questions for which the answer could be selected from the list of 5 possible answers, 20 yielded an ambiguous answer, meaning that the answers were not grouped enough around the median, in this case treated as the result.

A higher percentage of ambiguity was achieved in the case of "yes" or "no" questions. In this case, slightly over half of the questions (36 out of 69) did not yield an unambiguous answer that is the concurrence of at least 2/3 of the respondents. In summary, over 1/3 of the questions (38%) yielded an ambiguous answer.

For some of the issues, sufficient concurrence of the respondents' answers was achieved. This was the case with the question about the importance of water management (question no. 1), about the acceptance for the new approach to natural hazards (question no. 3) and the anticipated water quality (question no. 9). The questions about individual water usage (question no. 7), investment activity (question no. 10) and pro-environment changes in the structure design and development standards (question no. 11) have yielded single ambiguities. The other six questions have had more of them. The answers to the question about individual water usage (question no. 7) were especially difficult to interpret in the context of answers to the related question no. 8 about water demand in specific sectors.

As a result, the following discussion points for possible clarification during a meeting with the respondents have been identified:

- Question no. 2 Acceptance/rejection of IWRM - except from the sustainable scenario, heavy polarisation of views regarding most of the rules was discussed.
- Question no. 6. Economic instruments - only individual economic instruments were deemed significant by a majority of the respondents. As for the majority of the instruments, there is a consensus that they are not important. A perceptible lack of concurrence regarding the instruments was discussed.

- Question no. 7 regarding the water usage for each task of water management. If the answers indicate that there will be no significant rationalisation of water usage, then why so.
- Question no. 12 related to safety culture. For the market and regional scenarios, there were very few changes for good (even in the area of knowledge and awareness among specialists and citizens). Why such a pessimistic view of the future was revealed.
- Question no. 4. Hierarchy of water management tasks - evident blurring of the results was observed and discussed.

The results of poll research have revealed significant discrepancies in the experts' assessments. Workshop discussions of expert groups have also signalled significant uncertainty in assessments of directions and the scale of changes in water management, conditioned by hypotheses regarding the future socio-economic developments.

#### **4. Results analysis and identification of the sources of uncertainty**

The results of the poll research have been analysed during workshops with experts. Below are discussed the basic conclusions arising from the conducted discussions in regard to two scenarios for which the most significant polarisation had occurred.

##### ***Market scenario***

Among the most contested rules for integrated water resources management of this scenario are:

- “Water as the fundamental factor shaping the functioning of ecosystems.”

This rule may be questioned due to the fact that policy in this scenario will be focused on economic development, which will be the superior goal. In this situation, the environment and water issues would rather be an inferior goal. The economic balance would take priority, neglecting the environment.

- “Implementing economic rules in water economy based on the principle of full reimbursement of the costs of water services.”

It has been decided that flood protection, navigation and agriculture would not be subject to the reimbursement principle. As for the other issues regarding water prices, we will be approaching the full costs reimbursement principle.

- “Integral approach to surface water, underground water and water-dependent ecosystems.”

## SOURCES OF UNCERTAINTY IN FORMULATION OF THE COGNITIVE SCENARIOS FOR DEVELOPMENT OF WATER MANAGEMENT

Similarly to the "water as a fundamental factor in the functioning of ecosystems" principle, this rule will not be a priority, because the superior goal would be economic growth. Water-related issues may not be taken into account in a comprehensive manner, because the environmental problems will not be a priority. The issue of integral approach to underground waters in the area of agriculture may present a problem. Currently, agriculture is using underground water (for livestock breeding and irrigation) and may use underground water in the future.

- “Participation of the public in management - participation of users, industry institutions and the public in the water resources management process.”

It has been decided that participation of the public may not be fully accepted due to previous experiences in this scope, and will be marginalised through incomplete inclusion of the public into the water resources planning and management process, being limited mainly to informing about taken actions and plans. Social participation may be implemented to a limited degree also due to the fact that there is no pressure from the public regarding their will to become engaged, participate in planning and solve problems.

### *Regional scenario*

The IWRM principles, which may be met with the most significant lack of acceptance in this scenario, are:

- “Integral approach to surface water, underground water and water-dependent ecosystems.”

This principle may encounter lack of acceptance due to low social awareness regarding IWRM, as well as the current trend, which can also continue in the future, of putting the man's interest before the interest of the environment. Too low a quality of social life in Poland, as well as lower level of socio-economic development compared to the society of the Western Europe (other EU countries) may prove to be a significant barrier for introducing this principle.

- “The drainage basin approach in water resources planning and management.”

Despite the fact that this principle is currently taken into account in water economy policy and management, a possible threat for efficient drainage basin management both present and in the future could be the occurring administrative borders, especially when it comes to international regions (e.g. the Carpathian region), where priorities of two countries can often differ.

- “Participation of the public in management - participation of users, industry institutions and the public in the water resources management process.”

This principle, similarly to present, also in the future may not be fully implemented, because the public would not be actually involved in the planning and decision-making. On one hand, the reason for such approach is lack of common public interest, low level of development of democratic society in Poland, which does not facilitate wider engagement of local communities in jointly solving problems. Introduction of this principle would require a large work input from experts, decision makers, because the public would need to be "educated" in regard to the IWRM and prepared to participate in decision making. On the other hand, the decision makers develop plans, make decisions, and the public is only informed about the actions taken - it is not treated subjectively. Marginalisation of public participation is rooted in a systemic problem, which "limits" the public participation mainly to informing and does not seek full participation in water resources management (jointly planning the solutions).

- “Implementing economic rules in water economy based on the principle of full reimbursement of the costs of water services.”

The principle of full reimbursement of water services will encounter lack of acceptance both from the public, which might fear higher costs of e.g. the water and sewage bills, as well as the industry institutions, for which the lack of transparent financial regulations might be problematic. Another barrier is the "socialist" way of thinking, which transfers some of the costs to the state, or lack of trust for systemic solutions.

Conclusions drawn from the workshop discussions point to the fact that uncertainty in formulating scenarios for development of water management has its sources in:

- lack of faith in the scientific development, which ensures advancement, including small communities in actions, presenting the science to the public,
- focusing only on the obvious problems, not taking into account the network of interconnections,
- underestimating problems,
- schematic thinking based on the current canon of knowledge and decision making process,
- too long time perspective limiting the options for planning,
- thinking within the administrative and geopolitical borders,
- preferring temporary solutions,
- rejecting the history,
- thinking about technological limitations,
- thinking in closed groups,

- thinking in categories of preference,
- omitting unlikely but costly hazards in the analysis.

For the purpose of the latest IPCC report, a new generation of Socio-Economic Pathways (SSPs) scenarios (O'Neill, B.C., et al 2015) has been developed; these, to a larger degree than the previous scenario analyses, account for uncertainty related with climate changes. This uncertainty complements the list above.

## **5. Conclusion**

The adopted methodology for scenario development, as shown in the previous chapters, seeks to describe alternative vision for the future, shaped by the underlying assumptions for future development. The experience of the research shows that, given the many uncertainties affecting the water management, the development of alternative scenarios for water management needs to include expert consultations. The selection of an expert group is also important to ensure the right balance between the experts from the administration and the representatives of scientific units involved in the broader water management. It is also important that questions in the survey should take into account social aspects related to water management. Both the presented results of scenarios, as well as the identified uncertainties are valuable information for those making decisions regarding water management in Poland. Creating water management strategy in particular may account for experiences and results of the presented scenario development process - a vision for development of water management in Poland.

## **6. Acknowledgements**

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## ***Źródła niepewności w formułowaniu scenariuszy poznawczych rozwoju gospodarki wodnej***

### ***Streszczenie***

Niepewność jest często przeszkodą w procesie podejmowania decyzji, stąd poznanie jej źródeł może ułatwić ten proces i zwiększyć jego skuteczność. Celem artykułu jest identyfikacja źródeł niepewności w planowaniu w gospodarce wodnej, które zostały ujawnione dzięki przeprowadzeniu procesu tworzenia scenariuszy poznawczych w projekcie Klimat (POIG.01.03.01-14-011/08). W artykule omówiono scenariusze rozwoju gospodarki wodnej i proces ich tworzenia w projekcie Klimat. Przedstawiono przegląd literatury ukazujący inne projekty, w których przeprowadzono analizy scenariuszowe tego typu na świecie. Przedstawiono metodę formułowania scenariuszy rozwoju gospodarki wodnej oraz jej wyniki, które ujawniają źródła niepewności w planowaniu w gospodarce wodnej.

***Słowa kluczowe:*** scenariusz, woda, zarządzanie, ekspert.