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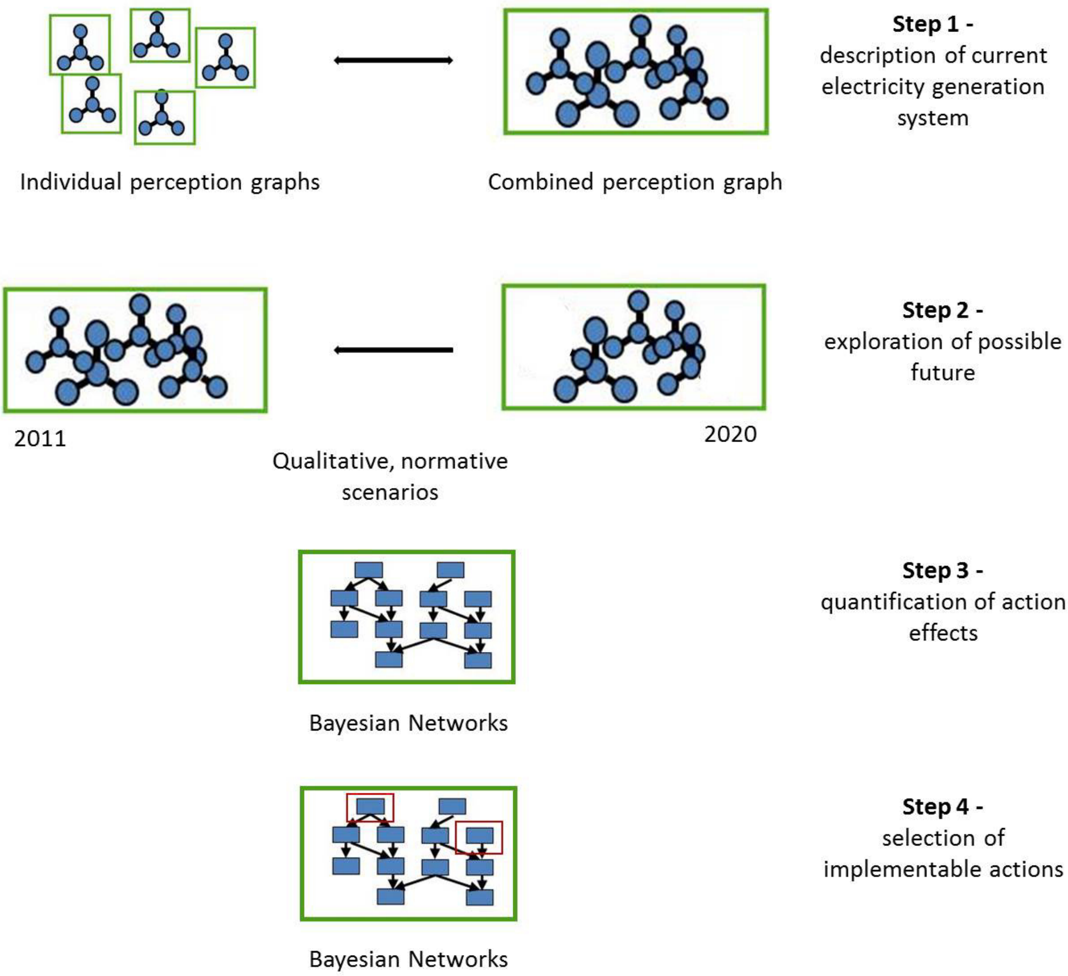
Design, implementation and evaluation of a participatory strategy development - A regional case study in the problem field of renewable electricity generation



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Design, Implementation and Evaluation of a Participatory Strategy Development – A Regional Case Study in the Problem Field of Renewable Electricity Generation

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Abstract

Transforming the current rather centralized electricity generating system into a climate neutral system based on renewable energy is an important approach to reduce greenhouse gas emissions and thus mitigate climate change. Stakeholders have each of them their own perception of the best strategies to achieve such a transformation. All perspectives are equally legitimate and needed for developing a specific transformation strategy suited for the region in focus.

This PhD thesis presents a four-step strategy development process for promoting power generation based on renewable electricity in the exemplary case study of a county, Groß-Gerau, near Frankfurt am Main, Germany. Relevant stakeholders represented the county authority, power plant operators, mutual savings bank, and Non-Governmental Organizations in the participatory process. In a transdisciplinary approach, a new combination of participatory methods was implemented and evaluated, including actor modeling (AM), development of qualitative normative scenarios and participatory Bayesian Network (BN) modeling. A literature review revealed that BNs as participatory modeling approach possess the potential to be a central method of transdisciplinary research; as a consequence, BNs were developed for this case study. The applied methods were evaluated with regard to their ability to (1) map the diversity of stakeholders' perspectives, (2) reflect the complexity of the problem, (3) take into account the uncertainty in the problem field, and (4) support the identification of mutually agreed, implementable and coherent strategies to obtain the promotion of renewable energy generation. The evaluation shows that the criteria were mostly fulfilled. The application of AM completely fulfills criteria number 1 and 2, while the development of normative scenarios addressed criterion number 3. Criterion number 4 was only partly fulfilled, following the lack of credibility in results of the Bayesian Network modeling which was caused by the high uncertainty of the conditional probabilities elicited from experts in the case study. In addition, stakeholders were not sufficiently involved in the construction and application of

BNs. Recommendations for an improved design and implementation of the participatory strategy development are given.

Another aspect covered in the PhD thesis is “social learning” for which participatory processes are essential. However, there is a lack of a clear definition of this term and related methods that quantitatively measure social learning. Here, social learning was defined as “as a series of semi-facilitated and semi-structured interactions between a heterogeneous group of stakeholders resulting in a change in social cognition of the participants and the relationships they have with one another”. Seven components relevant for the social-cognitive and social-relational dimension of social learning were selected from literature. The fulfillment of the components was evaluated with a combination of qualitative and quantitative methods that included an innovative before/after comparison of the perceptions of the stakeholders, a questionnaire, and telephone interviews. The applied methods were suitable for evaluating the selected components of social learning.

The evaluation of social learning for the case study and additional information showed that stakeholders do not trust each other. A literature analysis was performed which identified five factors that positively influence trust building between stakeholders. These factors are (1) mutual understanding of individual stakeholders’ societal values, (2) enhanced fair, balanced, trustworthy communication, (3) skilled facilitation and mediation, (4) availability of a core of knowledge, and (5) minimization of stakeholder turnover impacts.

The participatory strategy development is a recursive and iterative process that needs to be continually adapted as the process evolves.

Zusammenfassung

Der durch anthropogene Treibhausgasemissionen verursachte Klimawandel und seine Folgen für Menschen und Ökosysteme sind ein reales und komplexes Problem. Die Reduzierung der Treibhausemissionen ist eine Möglichkeit, die fatalen Auswirkungen des Klimawandels zu minimieren. Deutschland strebt bis zum Jahre 2020 eine Reduzierung des Treibhausgasausstoßes um 40% und bis zum Jahre 2050 um 80% an.

Um die nationalen Ziele zu erreichen, bedarf es einschneidender Eingriffe auf lokaler bzw. regionaler Ebene. Ein mögliches Handlungsfeld ist die Umgestaltung der eher zentralen Energieversorgung in ein klimaneutrales System mit einem erheblichen Anteil an erneuerbaren Energien. Über die zu ergreifenden Maßnahmen für eine solche Transformation besteht Uneinigkeit. Die verschiedenen Ansichten und Perspektiven auf die Umgestaltung der Energieversorgung müssen in die Entwicklung einer auf die Region abgestimmten Strategie einfließen und berücksichtigt werden, d.h. die relevanten Stakeholder mit ihren unterschiedlichen Ansätzen sind an der Entwicklung einer Strategie zu beteiligen. Ein partizipativer Strategieentwicklungsprozess auf regionaler Ebene weist die folgende Vorteile auf: (1) er unterstützt in einem Stakeholder-Netzwerk, bestehend aus Stakeholdern aus der Politik, Nicht-Regierungsorganisationen, dem privaten Sektor und der Wissenschaft, die Generierung von Lösungsansätzen; (2) durch die Einbindung der Stakeholder in den Lösungsprozess werden die entwickelten Strategien besser umgesetzt; (3) es stehen konsistente Daten zur Verfügung und (4) es müssen weniger Zusammenhänge und Ursachen als auf der globalen Skala berücksichtigt werden.

Verschiedene partizipative Modellierungsmethoden sind entwickelt worden, um eine Strategieentwicklung zu unterstützen. Wie genau der Einsatz von partizipativen Modellierungsmethoden die Strategieentwicklung tatsächlich fördert , bleibt bisher

eine offene Frage, ebenso, ob der partizipative Prozess soziales Lernen zwischen den Stakeholdern fördert und wie soziales Lernen evaluiert werden kann.

Die vorliegende Dissertation legt ihren Schwerpunkt auf die Entwicklung, Implementierung und Evaluation einer transdisziplinären Methodik zur Unterstützung einer partizipativen Strategieentwicklung. Dazu wurden innerhalb eines Strategieentwicklungprozesses zum Ausbau der Regenerativstromerzeugung die folgenden Methoden kombiniert: die Akteursmodellierung, die qualitative normative Szenarioentwicklung und die partizipative Modellierung mit Bayes´schen Netzen. Anschließend soll dann eine Methodik zur Evaluation sozialen Lernens in partizipativen Prozessen entwickelt werden.

Der theoretische Hintergrund transdisziplinärer Forschung wird in Kapitel 2 dargelegt. Transdisziplinäre Forschung wird in dieser Arbeit als ein Prozess definiert, in dem eine soziale, moderierte Interaktion Werte und Wissen aus der Praxis (Stakeholderwissen) in die Forschung einbindet. Die nachfolgenden vier Kapitel, entstanden in Zusammenarbeit mit anderen Autor_innen, geben unterschiedlichen Schwerpunkten bezüglich der Fragestellung Raum. Kapitel 7 führt die Ergebnisse in einer Synthese zusammen.

Partizipative Modellierungsmethoden sollen u. a. durch die Integration unsicheren Wissens von Wissenschaftlern und Stakeholdern über komplexe Mensch-Umwelt-Systeme die transdisziplinäre Strategieentwicklung im Umweltmanagement unterstützen. Kapitel 3 zeigt in einer umfassenden Literaturstudie auf, dass Bayes´sche Netze als partizipative Modellierungsmethode diese Anforderung erfüllt und damit das Potenzial besitzt, zu einer Kernmethode der transdisziplinären Forschung zu werden. Die Literaturstudie erfasst die Anwendung Bayes´scher Netze als partizipative Modellierungsmethode aus 30 veröffentlichten Fallstudien der letzten Jahre (2001 bis 2011) und destilliert, unter Berücksichtigung von drei Leitfäden zur Erstellung von Bayes´schen Netzen, Empfehlungen für die Nutzung im Umweltmanagement. Stärken und Schwächen Bayes´scher Netze treten zu Tage: Bayes´sche Netze eignen sich sehr gut, Wissen aus verschiedenen Disziplinen oder Sektoren (z.B. akademischer, nicht akademischer) zu integrieren. In Bayes´schen Netzen wird explizit Wissen über Unsicherheiten berücksichtigt und transparent dargestellt. Es können verschiedene Eingangsdaten für das Modell genutzt werden, und die benutzerfreundlichen Softwareprogramme für Bayes´sche Netze haben kurze Rechenlaufzeiten. Die Nutzung Bayes´scher Netze unterstützt die Kommunikation und das Lernen zwischen Stakeholdern. Schwächen zeigen Bayes´schen Netze bei der Modellierung räumlicher Variabilität, zeitlicher Dynamiken und Rückkopplungsschleifen. Zudem können die Erstellung der konditionellen Wahrscheinlichkeitstabellen und auch das Verständnis der probabilistischen Darstellung der Modellierung für Stakeholder schwierig sein. Die Genauigkeit und auch die Glaubwürdigkeit der Modellierungsergebnisse sind eingeschränkt.

Kapitel 4 beschreibt detailliert die Fallstudie „Regenerativstromerzeugung in Groß-Gerau" als eine transdiziplinäre, partizipative Strategieentwicklung. Groß-Gerau, ein Landkreis südwestlich von Frankfurt mit einer Fläche von 453 km^2 und ca. 252 000 Einwohnern, verfolgt das Ziel, im Jahr 2020 seine Stromversorgung mit einem Anteil von 30% Regenerativstrom zu leisten. Im Jahre 2007 lag der Anteil der Regenerativstromerzeugung am Gesamtstromverbrauch bei unter einem Prozent. Das Potenzial der Regenerativstromerzeugung wurde in einer Studie auf das ca. Zwanzigfache der Höhe des Gesamtstromverbrauchs geschätzt. Als Schlüsselstakeholder in dem partizipativen Prozess agierte das Energiekompetenzcenter (EKC) des Landkreises Groß-Gerau. Das EKC spielte sowohl eine wichtige Rolle bei der Auswahl der teilnehmenden Stakeholder als auch während der Workshops als Meinungsbildner und Multiplikator der Workshopergebnisse. Insgesamt wurden dreizehn Stakeholder als Teilnehmer am partizipativen Prozess eingeladen. Darunter befanden sich Repräsentanten des regionalen Energieerzeugers und Netzbetreibers, der regionalen Stadtwerke, einer Bank, Vertreter der Kommunen und des Kreises als auch Vertreter von Nicht-Regierungs-Organisationen wie dem Bauernverband und Naturschutzverbänden, der Industrie- und Handelskammer und Handwerkskammer. Der partizipative Prozess dauerte insgesamt ein Jahr (Oktober 2011 bis November 2012) und es wurden vier Workshops durchgeführt. Innerhalb des transdisziplinären Forschungsprojektes wurden neben verschiedenen Kommunikationsmethoden die Akteursmodellierung, die qualitative normative Szenarioentwicklung und die partizipative Modellierung mit Bayes´schen Netzen kombiniert. Der Strategieentwicklungsprozess bestand aus vier Schritten: (1) Beschreibung des aktuellen Elektrizitätserzeugungssystems aus Sicht der Stakeholder (Akteursmodellierung); (2) Erkundung möglicher Zukünfte (qualitative, normative Szenarioentwicklung); (3) Quantifizierung verschiedener Handlungen und deren Auswirkungen auf die Ziele des Kreises hinsichtlich der Regenerativstromerzeugung (Bayes´sche Netze) und (4) Identifizierung umsetzbarer (kurzfristiger) Handlungen (Bayes´sche Netze). Mithilfe eines Fragebogens für die anwesenden Stakeholder (n=10) wurden im letzten Workshop die eingesetzten Methoden evaluiert. Folgende Kriterien sollten die Methoden erfüllen: (1) Herausarbeiten der Diversität der Stakeholderperspektiven auf das Problem; (2) Darstellung komplexer Sachverhalte innerhalb des Problems; (3) Berücksichtigung von Unsicherheit; (4) Unterstützung der Identifizierung von umsetzbaren und abgestimmten Strategien. Die Einschätzung der Forscher und die Evaluierung durch die Stakeholder zeigten deutlich, dass die Akteursmodellierung, so wie in der Fallstudie angewandt, die Kriterien 1 und 2 sehr gut erfüllt. Elemente der Akteursmodellierung (kombinierter Wahrnehmungsgraph) wurden besser beurteilt, Kriterium 2 zu erfüllen, als die Bayes´schen Netze. Die qualitative, normative Szenarioentwicklung wurde als geeignete Methode bewertet, Unsicherheiten des Systems zu berücksichtigen (Kriterium 3). Die Bayes´schen Netze wurden für wenig tauglich befunden, umsetzbare Handlungen zu detektieren (Kriterium 4). Diese Einschätzung lässt sich zum einen mit teilweise fehlender Partizipation der Stakeholder in der Konstruktion und Anwendung der Bayes´schen Netze erklären. Die Verfasserin der Arbeit geht davon aus, dass bei einer intensiveren Einbindung der Stakeholder eine bessere Evaluation der Bayes´schen Netze, d.h. eine höhere Glaubwürdigkeit der Modellierungsergebnisse, erzielt worden wäre. Zum anderen zeigten die konditionellen Wahrscheinlichkeiten aus Sicht der Experten große Unsicherheiten, da es kaum empirisches Systemwissen über das neue Problemfeld der regenerativen Stromerzeugung, insbesondere der Auswirkungen von Handlungen wie z.B. Öffentlichkeitsarbeit, gibt. Bis dato fehlt es an passenden Methoden, soziales Lernen der Stakeholder während einer Teilnahme am partizipativen Prozess zu detektieren.

Kapitel 5 beschreibt die Evaluation sozialen Lernens auf Seiten der Stakeholder. Soziales Lernen wird in dieser Arbeit definiert als „eine Folge teilweise moderierter und teilweise strukturierter Interaktionen zwischen einer heterogenen Stakeholdergruppe die zu einer Veränderung der sozialen Wahrnehmung der Teilnehmer und der Beziehungen unter den Stakeholdern führt“. Sieben ausgewählte Komponenten sozialen Lernens wurden mit einer Kombination verschiedener Methoden evaluiert. Die ausgewählten Komponenten sozialen Lernens decken den sozial-kognitiven Bereich ((1) Bewusstsein für die teilweise unterschiedlichen Ziele und Perspektiven der teilnehmenden Stakeholder; (2) geteilte Problemwahrnehmung; (3) Verständnis für die Abhängigkeit der Stakeholder untereinander; (4) Verständnis für die Komplexität des Problems) und den sozial-emotionalen Bereich ((5) Lernen zusammen zu arbeiten; (6) Vertrauen in die anderen Stakeholder und (7) Knüpfung von informellen und formellen Beziehungen) ab. Eine aus unterschiedlichen Ansätzen entwickelte neue Methode erfasst anhand von Wahrnehmungsgraphen die Veränderung in der Wahrnehmung der Stakeholder hinsichtlich der sozial-kognitiven Komponenten vor (2 bis 3 Wochen vor dem ersten Workshop) und nach (10 bis 12 Wochen nach dem letzten Workshop) dem partizipativen Prozess (n = 7). Mit einem Fragebogen wurden die Meinungen der Stakeholder (n=10) zu den Komponenten 5 bis 7 erhoben. Um die langfristigen Auswirkungen des Prozesses zu evaluieren, wurden Telefoninterviews mit fünf Stakeholdern (Anlagenbetreiber, Bank, Vertretern der Kommune (Energiebeauftragter und Umweltamtsleiter), Naturschutzorganisation) zwei Jahre nach dem letzten Workshop geführt. Die Interviewpartner waren aufgefordert zu beschreiben, welche Veränderungen sie auf individueller und institutioneller Ebene beobachten konnten und wie sich der partizipative Prozess auf die Zusammenarbeit zwischen den teilnehmenden Stakeholdern ausgewirkt hat. Die Ergebnisse zeigen, dass die innovative neue Methode zur Detektion von Veränderungen der Wahrnehmungen gut geeignet ist um die Komponente 2 und 4 zu evaluieren. Schwächen zeigt die Methode bei der Evaluation der Komponenten 1 und 3. Hier ist es schwierig, die erhobenen Informationen den Komponenten exakt zu zuordnen. Es wurde deutlich, dass ein gut ausgearbeiteter Fragebogen Aussagen über die Evaluation aller einzelnen Komponenten erlaubt. Die Telefoninterviews nach zwei Jahren zeigten, dass hauptsächlich Auswirkungen des partizipativen Prozesses auf der individuellen Ebene festgestellt wurden. Stakeholder, die soziales Lernen erfahren, haben bilden die Ausgangsbasis um gesellschaftliche Effekte anzustoßen. Die Literatur nennt das Spielen von Brettspielen unter Beobachtung unabhängiger Psychologen während des Workshops als eine Evaluationsmethode der Kriterien 3 bis 5. Zukünftige Forschung sollte hier die bereits vereinzelt bestehenden Ansätze, die Aussagen über die gesellschaftlichen Auswirkungen partizipativer, transdisziplinärer Forschungsprozesse ermöglichen, weiter entwickeln.

Die Evaluationsergebnisse des Fragebogens als auch Aussagen der Stakeholder während der Interviews und Workshops zeigen, dass Vertrauen in die anderen Stakeholder als eine Komponente sozialen Lernens (Komponente 6) nur teilweise entwickelt wurde. Es ist anzumerken, dass der Fokus des transdisziplinären Forschungsprojektes nicht auf der Schaffung von Vertrauen zwischen den Stakeholdern lag.

Kapitel 6 eruiert aus der Retrospektive, basierend auf Ergebnissen anderer Studien, welche Faktoren Vertrauen zwischen den Stakeholdern beeinflusst bzw. schafft. Die Literaturstudie identifiziert fünf Faktoren: (1) gemeinsames Verständnis für die Werte der Stakeholder in einem partizipativen Prozess; (2) gerechte, gleichverteilte und vertrauensvolle Kommunikationsweise; (3) kompetente Moderation und Mediation; (4) Vorhandensein eines Kernes an gemeinsamen Wissen, (5) Minimierung der Auswirkungen möglicher Stakeholderausfälle oder Wechsel von Stakeholdern. Nicht alle dieser Faktoren können durch die den Prozess organisierenden Forscher beeinflusst werden. Jedoch lässt z.B. durch eine intensive Kennenlernphase der Vertrauensaufbau zwischen den Stakeholdern direkt am Anfang des partizipativen Prozesses stimulieren, und die folgenden Workshops können verstärkend in den Räumlichkeiten

(Arbeitsplatz) der Stakeholder durchgeführt werden. Dies bietet die Möglichkeit, die Stakeholder in ihrem Umfeld fortlaufend näher kennenzulernen.

Die in dieser Dissertation durchgeführte transdisziplinäre Untersuchung vereint wichtige Erkenntnisse zur Anwendung partizipativer Modellierungsmethoden innerhalb einer Strategieentwicklung und der Evaluation sozialen Lernens während eines solchen Prozesses. Eine partizipative Strategieentwicklung ist ein rekursiver und iterativer Prozess, der an den Verlauf der Strategieentwicklung stetig angepasst werden muss.

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AM	Actor modeling
BN	Bayesian Network
CN	Causal Network
CPT	Conditional Probability Table
EEG	Erneuerbare Energien Gesetz
EKC	Energiekompetenzcenter (Energy Competence Center)
PG	Perception Graph
PG_COM	combined Perception Graph
PG_IND	individual Perception Graph
PG_ORG	original Perception Graph
PSD	Participatory Strategy Development
PV	Photovoltaics
REG	Renewable Electricity Generation

1

Introduction

1.1 Context and motivation of the study

Global annual anthropogenic greenhouse gas emissions are currently increasing [1]. An increase in greenhouse gas emissions causes a raise in the global average temperature that has several dramatic and hardly manageable consequences for the global ecosystems. The United Nations Framework Convention on Climate Change (unfccc.int) aims at the stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner. According to the IPCC report [1], 47% of the greenhouse gas emissions are directly deriving from energy supply; while industry causes about 30%, transport about 11% and building sector 3%. Mitigation of climate change as a human intervention to reduce the sources or enhance the sinks of greenhouse gases is important to protect natural resources. In Germany, the goal to transform the energy generation system towards a climate friendly system based on renewable energy has become an important step to mitigate climate change. Germany aims at reducing about 40% greenhouse gas emissions in 2020 in comparison to 1990 and about 80% in 2050 (BMUB online, http://www.bmub.bund.de, accessed 10.03.2015). The transformation of the energy generation system has gained a broad consensus at the national level [2].

Transdisciplinary research is a new research mode aiming at generating robust knowledge from scientists and stakeholders on how to solve complex and uncertain real-world problems. At the regional (in this case county) level where national goals have to be implemented, participation of local stakeholders has proven especially important [3]. A transdisciplinary process on a regional level has various advantages: (1) less interactions and less causes and impacts need to be taken into account on a regional level in comparison to a global scale [4]; (2) more consistent data exists; (3) a certain ability to support the generation of knowledge to tackle a problem in multi-stakeholder networks that are composed of stakeholders from policy, NGOs, private sector and university [5]; (4) the developed outcomes might be better implemented.

Stakeholder involvement in transdisciplinary project requires careful application of participation mechanisms and methods to contribute to the generation of implementable and valuable outcomes [6].

Participation

The mechanisms of participation that have mostly been used in participatory processes are stakeholder workshops [7–10]. Although levels of documentation in literature vary, it is difficult to determine systematic design components of the workshop mechanisms in most cases. In addition to the lack of systematic design components of the workshop mechanisms, stakeholders in the participatory process are often treated as receivers of information at the end of a scientific or planning exercise [11]. Kloprogge & Sluijs (2006) [12] identify the openness of different stages of a project to participation as an indication of the quality of the participation opportunities and interactivity in the process. Interactivity in this context refers to the relationships between the research team stakeholders involved in the process [13] As participatory processes intend to address complex problems in human–environment systems and to create socially robust and solution-oriented knowledge, the design of participatory processes needs to adapt. The main implication is to move from the predominately transmissive or extractive models of engagement to the co-development of knowledge [14], negotiating and integrating inputs from stakeholders outside the research team at various stages of the participatory process. This mode of doing research is transdisciplinary research (chapter 2.1). Although consensus emerges around the argument that participation requires interactive participation, there is still room for interpretation when and how and to what extent interactivity is required. The degree of interactivity in a participatory process is not a given, but rather is dependent on contextual factors.

Methods

The choice of appropriate methods to support a participatory process is essential [15]. Participatory methods are used to structure group processes as well as to facilitate non-experts to play an active role and to articulate their knowledge, values and preferences for different goals. The methods applied in a participatory process needs to fulfill the following requirements according to literature: (1) to map out the diversity of stakeholder perspective [16], (2) to grasp complexity [17], (3) to take into account the uncertainty in the problem field [18] and (4) to support the identification of mutually agreed, implementable and coherent strategies (policy outcomes). The first requirement to map out the diversity of stakeholders is important due to the fact that each of the stakeholders has a specific perception on the problem and how to solve this problem. While it is necessary to represent the complex system as simple as possible, the ability to grasp the complexity of the problem is needed to focus on the problem to be addressed. Uncertainty is a mainstay of a complex problem and needs to be considered in problem solving processes. The traditional approach to deal with uncertainty was to carry out more and better analysis to decrease uncertainty [19]. However, these deterministic forecasting approaches have limits due to lack of data and knowledge. Wack (1985) [20] states that uncertainty must be accepted as a structural feature of complex problems and that fundamentally different futures are conceivable that are not simply variations of a single base case. In the face of uncertainty, decisions cannot be made based on the 'right' answers, but rather become a question of which choices might work best in the face of very different possible futures [21].

Outcomes

A participatory process aims at two different outcomes. On the one hand a participatory process should support policy outcomes like an implementable and coherent strategy to tackle complex problems. Another important process outcome is social learning among researchers and stakeholders [22]. Social learning can not only improve the quality of the policy outcomes. It can have long-term impacts beyond a particular process, in the form of improved relations. The detection and evaluation of social learning during a participatory process can be difficult [11, 23]. Therefore evaluations of social learning and the impacts of participation are often anecdotal [6]. As a consequence problem-based transdisciplinary research require the development of new criteria by which to evaluate the outcomes of participatory processes [24, 25].

1.2 The case study of this thesis: REG Groß-Gerau

It appears from the descriptions above that there is much room for the improvement of the design, implementation and evaluation of participatory processes. To contribute to this ongoing effort we set up a participatory process in the county of Groß-Gerau in Hesse, Germany.

The county of Groß-Gerau is located in the southwest of Frankfurt in the state of Hessen in Germany (Figure 1). It covers an area of 453 km² and has about 252,000 inhabitants. The goal of the county is to cover 30% of the electricity consumption from renewable energy sources by 2020 and produce the renewable electricity within the county. The current generation of renewable electricity is less than one percent of the electricity consumption (data from 2007 [26]). In Groß-Gerau the potential for the generation of renewable electricity is about 20 times higher than the electricity consumption in 2007 (Table 1-1).

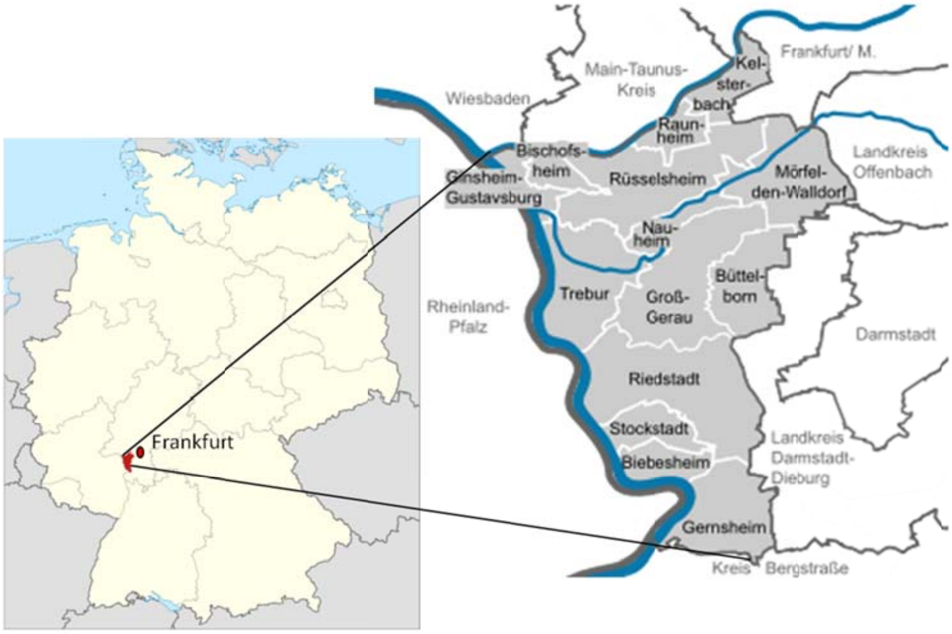

Figure 1-1: Location of the county Groß-Gerau in Germany. In the county Groß-Gerau the case study has been conducted (http://de.wikipedia.org/wiki/Kreis_Gro%C3%9F-Gerau).

A participatory process called "Renewable Electricity Generation in Groß-Gerau" (hereafter referred to as "REG Groß-Gerau") was initiated to develop strategies with representative of stakeholders to accelerate the renewable electricity generation within the county and thus to reach the 30% goal. Next to the developed strategies as policy outcomes, the participatory process aimed at social learning of the stakeholders.

Table 1-1: Actual and potential contribution of renewables to electricity generation in Groß-Gerau by different sectors; total electricity consumption in the county in 2007 was 1,246 Mio. kWh; data source:[26].

Energy source	**Contribution of renewables in 2007 (Mio. kWh/a)**	**Potential contribution of renewables (Mio. kWh/a)**
Biomass (in gaseous form)	5.4	27
Photovoltaics	6.4	1,233
Deep geothermal energy	0	22,962
Wind energy	0	222
Total	11.8	24,443

1.3 Research goals and questions

Much of the debate described above has to do with the lack of systematic documentation of design and implementation of participatory processes [6, 27] and the lack of assessment of impact of participatory processes [23]. This PhD has two main goals:

(1) Design, implementation and evaluation of a methodology that supports a participatory strategy development in the problem field of renewable electricity generation.

(2) Identification of implementable and mutual agreed strategies to promote renewable electricity generation in the county of Groß-Gerau, Germany.

The first goal is a scientific one and the second goal a practical one outside of academia. These goals will be reached by answering the following four research questions:

(1) What do we know about the application and applicability of Bayesian Networks as a participatory modeling tool in transdisciplinary research?

(2) How can a participatory process with its applied methods support the identification of a strategy for the acceleration of renewable electricity generation?

(3) What are measurable components of social learning and how can the participatory process be evaluated with regard to social learning and its components?

(4) How can the participatory process be improved with regard to trust development among stakeholders?

1.4 Outline of the thesis

The thesis is organized in seven chapters and presents the results of a case study "REG Groß-Gerau" to support the identification of a strategy to bring forward renewable electricity generation in the county. Chapter 2 provides the theoretical framework of this thesis. Chapter 3 is a literature review on how Bayesian Networks, as one applied modeling method of this study, were used in participatory modeling approaches for environmental management. Chapter 4 describes in detail the combination of participatory methods applied in "REG Groß-Gerau" and analyses the fulfillment of certain requirements of the participatory methods applied. The chapter concludes with a reflection on how the implementation of the method combination could be improved. Chapter 5 evaluates social learning among stakeholders as one important outcome of a participatory process. Chapter 4 and 5 are the core chapters of this PhD thesis. Chapter 6 introduces and discusses factors that support the development of trust among the stakeholders as important requirement of social learning in a participatory process. Chapter 7 syntheses the key findings of this study with regard to its scientific contribution and its contribution to the renewable electricity generation in Groß-Gerau. Finally the chapter provides an outlook for further research.

1.5 Authors´ contributions

Chapters 3 to 6 are manuscripts for articles that partly have already been published (chapter 3 and 6) or are submitted to scientific journals. Table 1-2 provides an overview on the publication status of each chapter.

Table 1-2: Overview of the publication status of the manuscripts of chapter 3 to 6.

Chapter	Authors	Title	Journal / Conference proceedings	Publication status
3	Meike Düspohl, Sina Frank and Petra Döll	A Review of Bayesian Networks as a Participatory Modeling Approach in Support of Sustainable Environmental Management	Journal of Sustainable Development	Published (Vol. 5, No. 12; 2012)
4	Meike Düspohl and Petra Döll	Causal Networks and Scenarios: Participatory Strategy Development for Promoting Renewable Electricity Generation	Journal for Cleaner Production	Published (Vol. 121, 2016)
5	Meike Düspohl, Tuck Fatt Siew Petra Döll and Arjen J. E. Wals	Social learning in a strategy development process – criteria and methods for evaluation: Lessons learned from a case study for Renewable Electricity Generation	Journal for Cleaner Production	Submitted
6	Meike Düspohl, Tuck Fatt Siew and Petra Döll	Building trust while modeling with stakeholders as requirements for social learning	Proceedings of the 7th International Congress on Environmental Modelling and Software	Published (2014)

The author designed and performed the research process conducted in the case study (see chapter 1.2) mainly autonomous with great support of the co-authors. The author contributed to the manuscripts presented in Table 1-2 as followed:

- Writing the manuscript of chapter 3 to 6. Sina Frank wrote in chapter 3 the subchapters 3.2 and 3.5. Petra Döll wrote the introduction (subchapter 3.1).
- Preparing figures and tables of chapter 3 to 6. Sina Frank created Figure 1 and 2 in chapter 3.
- Petra Döll reviewed the manuscript of chapter 3 to 5. Tuck Fatt Siew reviewed the manuscripts of chapter 3 to 6. Arjen E. Wals reviewed the manuscript of chapter 5.

2

Theoretical background: Transdisciplinary research for solving real-world problems

2.1 The real-world problem and the research approach

The beginning of this research is a real-world problem: The impacts of climate change needs to be minimized. Additionally in March 2011 the nuclear disaster in Fukushima increased the awareness of people regarding the danger of nuclear power supply. Politicians all over the world decided on how the energy supply systems of their countries could be quickly transformed. In Germany the elected government promotes directly after the disaster measures to phase out nuclear power. Connected to the external driver climate change, on national, regional and local level the questions arised: How can the world, each nation, region (in this case county) or city transform its electricity generation system towards a climate neutral system? Like many other real world problems this problems is characterized with a high degree of complexity, uncertainty and controversy [28]. In general real-world problems encompasses both its biophysical system consisting of stocks and flows of material and energy as well as the corresponding stakeholders and their values, interests, powers, and interrelations [24].

A transdisciplinary research is a type of research that aims at solving real-world problems by overcoming disciplinary boundaries e.g. between humanities and natural science. Transdisciplinary researchers have to step into problems like energy, ecology or healthcare that are not defined by a discipline [29] and engage in mutual learning [30]. Transdisciplinary research is a new research type, and describes a new mode of science different from multi- or interdisciplinary approaches [31]. In contrast to these, transdisciplinary research aims at producing socially robust knowledge that includes stakeholder knowledge [32] and is therefore characterized by a process of collaboration between scientists and non-scientists on a specific real-world problem. This requires a methodology and organization that goes beyond disciplinary research [13, 33]. Again knowledge and values from outside of academia are integrated into the research process. At the same time, the research process is opened up to the stakeholders, aiming at a mutual learning process [34]. Because of its ability to handle multi-actor, complex problems, transdisciplinary research is used extensively in the thematic field of sustainable development. Prominent areas of application in which interests of scientists and practitioners can be combined are regional development planning [13, 35], spatial planning [36], and urban studies [37].

The historical motivation to call transdisciplinarity out as a new research mode are the integration of knowledge from different scientific disciplines to solve a problem [29], the transformation of the relation between science and society [31], or the challenge of 'post-normal' science [38].

The definition used in this thesis for transdisciplinary research is emphasizing the process aspect of a social interaction [39] and the inclusion of values and knowledge from practice in research [40]. Transdisciplinary research is a complex endeavor and requires a suitable methodology and organization originating from a socio-cultural constructivist point of view [33].

2.2 Stakeholders and their participation

According to literature a stakeholder can be an individual or group, organized or unorganized, who has a stake or interest in a particular issue [41]. Stakeholders are either (1) involved in the decision-making process, (2) affected by the decisions made, or (3) not involved in the decision-making process but important for a successful implementation of decisions made [42]. Some examples of stakeholders include policy makers, planners and administrators in government, non-governmental organizations, and manufacturers. This transdisciplinary research project focuses on stakeholders as institutions and uses the term stakeholder reperesentative when referring to individuals participating in project.

Transdisciplinary research as defined above, has intended effects both in science and in practice. In practice the presented study aims at the identification of an implementable strategy to promote renewable electricity generation in the county of Groß-Gerau, Germany. A strategy is defined as specific actions that aim at a declared goal of the stakeholder representative. To understand stakeholders′ actions this study refers to the theoretical framework of action-oriented social geography. The action-oriented social geography point out that the decision taken by a stakeholder regarding an action he or she would prefer to promote energy electricity generation, is influenced by the individual biography of the stakeholder representatives, socio-political institutions and societal rules and geographical structures, resources and power [43]. Taken these different influencing factors into account stakeholders, decide not only due to their rationality. Stakeholders engaged in the transdisciplinary research project are not in a symmetric position. They have different roles, interests, power levels and relationships.

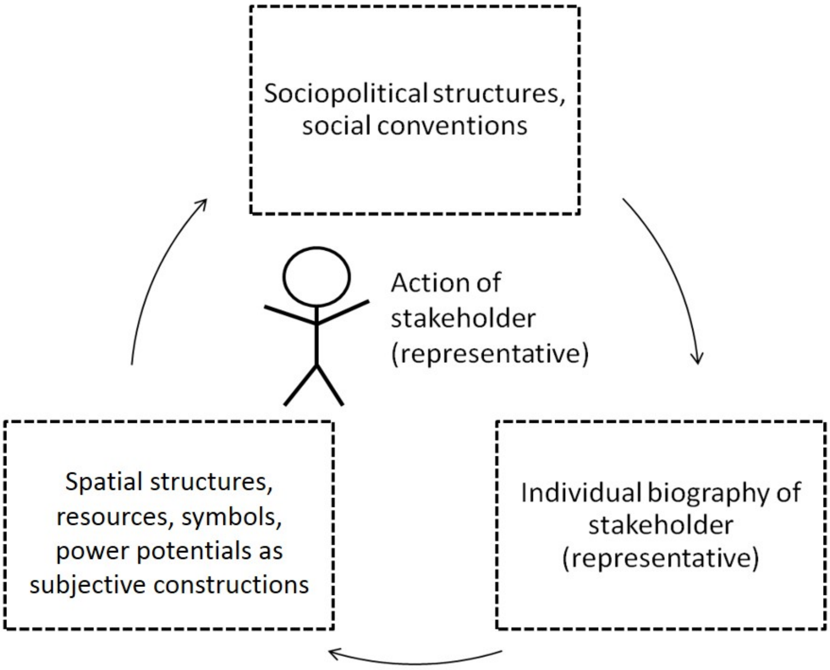

Figure 2-1: Factors according to the action-oriented social geography influencing the action of a stakeholder (based on Gebhardt et al. (2007) [44]).

2.3 Methods

The methods applied in this study are participatory modeling approaches are based on causal networks (actor modeling and Bayesian Network modeling) and participatory scenario development. Next to the participatory methods mentioned before several communication tools were used to inform the stakeholders before, during and after the workshops.

2.3.1 Causal network as models

Causal networks can be undirected or directed acyclic graphs consisting out of variables like actions, factors and goals that represent the system. The causal networks applied in the participatory process include three types of knowledge about the problem. The three types of knowledge [31] are uncertain knowledge about the genesis and development of the problem ("system knowledge"), knowledge about the different norms and values of the stakeholders ("target knowledge") as well as knowledge about options for change, depending system relations and goals ("transformation knowledge). These types of knowledge can be efficiently stored in the graphical structure of the causal network and be used to enhance the transfer of knowledge among stakeholders. The construction of causal network helps to structure the problem field and reduce complexity.

Causal networks model the problem field. The current perspective on models is the epistemic position of constructivism. Due to the assumption of constructivism [45], it is only partly possible to display a simple reality with models. Models (in this case causal networks) are not able according to action-oriented social geography to include all drivers that are relevant to understand how a system, described in the model, works. Driving factors like power relations or the individual biography of the stakeholder representative are not presented in the model. However models are useful on the one hand to support gaining knowledge by comparing statements in the models that are consistent. On the other hand models are useful to enhance the transfer of knowledge by structuring processes and problems and reducing complexity. Models include relevant information and allow reasonable predictions. According to Luhmann (1991) [46] symbolic generalized communication media like causal networks are only one of three media that decreases the unlikeliness of (1) understanding, (2) reaching the addressees and (3) success of acceptance of the message. The other two media are the media of language and the media of distribution that decreases the risk of finally not accepting the findings.

2.3.2 Methodological triangulation in the participatory process

Triangulation is defined according to Denzin (1978) [47] as the combination of methods to investigate the same phenomenon. Denzin understand triangulation as a kind of validation. There are different types of triangulation like "data triangulation", which includes the collection of data during different times, different locations and by different people. The second type is the "investigator triangulation" that describes the engagement of different interviewers or observers to avoid subjective distortion. "Theory triangulation" means the application of different theoretical perspectives to describe and analyze the object of research. The core of Denzin´s concept is the "methodological triangulation". The methodological triangulation aims at a complex process to play different methods off against each other, and as a consequence to maximize the validity of field research.

According to Flick (1992) [48] the combination of methods cannot aim at getting a total picture of the phenomenon. The core critique of Denzin´s understanding is the use of triangulation as a kind of strategy to validate finding obtained. This implies that there is a reality and understanding of the object matter. The methodological triangulation finally deepens and broadens the analysis of the problem without aiming at detecting objective truth [48].

The transference of these theoretical assumptions supports the application of the combination of quantitative, semi qualitative and qualitative participatory methods in the participatory process. In other words, the methodological triangulation in the participatory process helps to deepen and broaden the understanding of the system that generates renewable electricity in Groß-Gerau.

The awareness of all restrictions of the involved people (stakeholder and researchers) and the applied methods in the participatory process described in this chapter however still allow the conduction of this transdisciplinary research that aims at the generation of scientific insights about the design (choice of methods) and implementation of a participatory process to support the identification of implementable strategies.

2.4 Being a transdisciplinary researcher – self-reflection

The researcher or analyst has a big influence on the participatory process and its outcomes by making assumptions and decisions about the application of methods. Figure 2-2 gives an overview about the decisions that were taken by the research during the entire participatory strategy development in Groß-Gerau. The figure point out that the researcher tries to make her influence transparent. The researcher or analyst herself is influenced by her individual biography, socio-political institutions and societal rules and geographical structures, resources and power, he or she is not aware of during the entire research [43].

On the other hand according to Renger et al. [49] scientists play five roles: facilitator, modeler, process coach, recorder and gate keeper. Another role is the owner of scientific knowledge in the field of renewable energies.

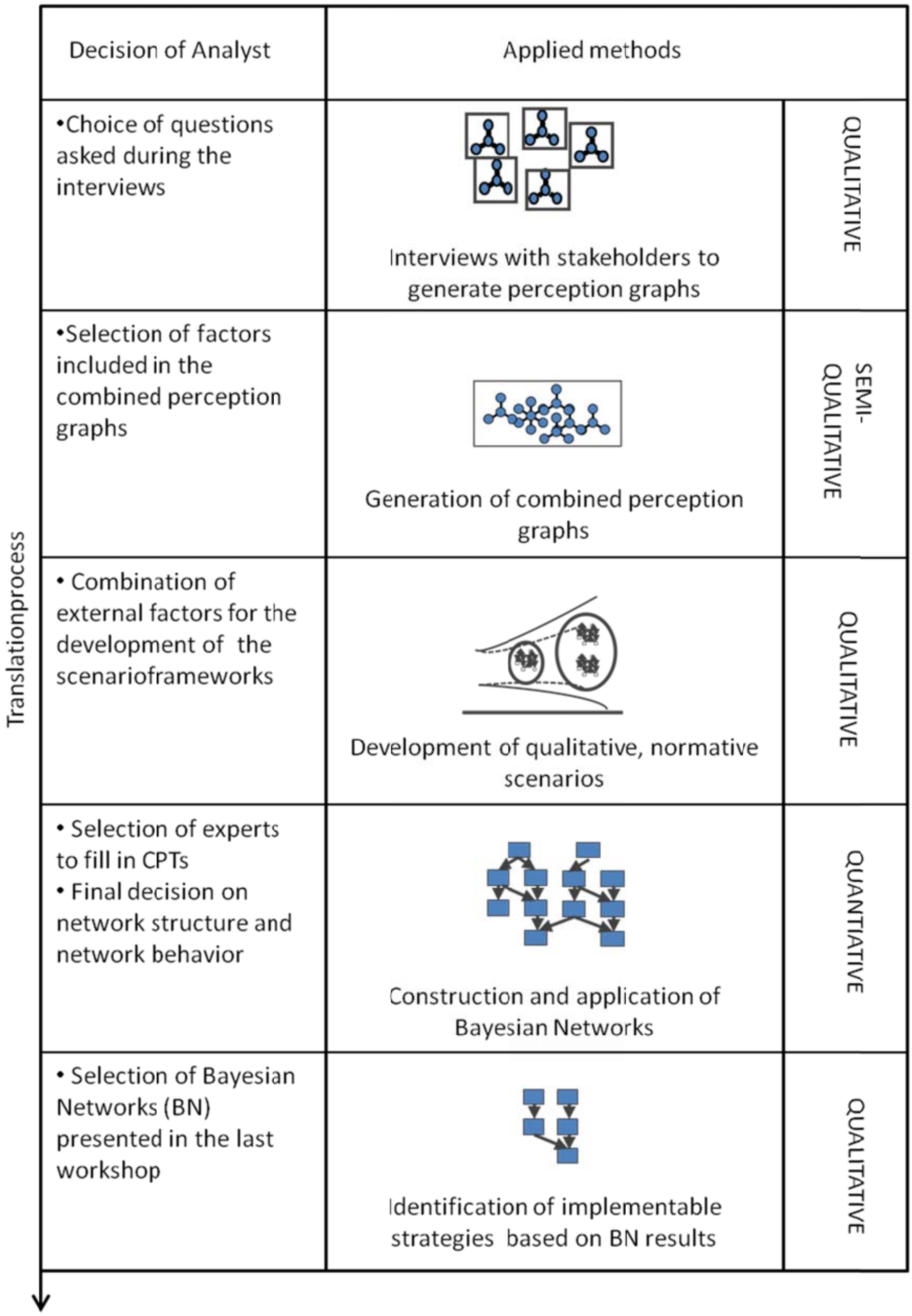

Figure 2-2: Decisions taken by the analyst during the research process that influences the process and its outcomes.

3

A review of Bayesian Networks as a participatory modeling approach in support of sustainable environmental management

Meike Düspohl, Sina Frank and Petra Döll

Journal of Sustainable Development, published (Vol. 5, No. 12; 2012)

3.1 Abstract

To support sustainable environmental management, uncertain knowledge about complex human-environment-systems from both inside and outside of academia needs to be integrated. Bayesian Network (BN) modeling is a promising method to achieve this, in particular if done in a participatory manner. Based on a review of 30 cases of participatory BN modeling of environmental problem fields, and of three guidelines, we summarize recommendations for BN modeling with stakeholder involvement. In addition, strengths and limitations of BNs are synthesized. We found that BNs were successfully applied for knowledge integration and identification of sustainable management strategies within participatory processes. Due to many favorable characteristics, BNs have the potential to become a core method of transdisciplinary knowledge integration in environmental management.

3.2 Introduction

Typically, sustainability-oriented environmental management and planning deals with problem fields that are characterized by (1) a significant degree of uncertainty or even ignorance and (2) different and equally legitimate perspectives on what is pertinent and what is best. This prevents identification of "optimal" management strategies based on purely scientific evidence [50]. Examples include integrated water resources management, climate change mitigation and adaptation, and approaches for dealing with man-made organic compounds that are potentially toxic for humans and other biota. For integrated water resources management that aims at optimizing ecosystem services, for example, there may be a need to estimate the impact of a certain water management measure on both farmer income and the health of riparian vegetation. All these problem fields are embedded in complex human-environment systems. Often, the environmental system itself is not well understood (e.g. how the riparian vegetation reacts to changes in river flow dynamics). Even more often, there is significant uncertainty about the interactions between humans and the environment or about the human system component that is relevant for the environmental system under consideration (e.g. how actions of farmers change in response to water pricing).

To better understand human-environment systems and to support the identification of sustainable management strategies, knowledge of multiple scientific disciplines and diverse stakeholders from various societal sectors has to be integrated [51]. A good system understanding ("system knowledge"), however, is not sufficient for sustainable environmental management that generally requires the endorsement and implementation of management measures by a multitude of stakeholders. In addition, knowledge about the different problem perspectives, values, and goals of the stakeholders ("target knowledge" according to [52]) needs to be generated and integrated, as well as knowledge about how to achieve common goals ("transformation knowledge", [52]). Generation of these three types of knowledge, if done jointly by scientists and stakeholders, can be regarded as "post-normal science" [38] and has more recently been referred to as "participatory integrated assessment" [6, 23] or "transdisciplinary research" [17, 30, 53]. An important goal of transdisciplinary research is social learning of the participants of the joint research process [50, 54].

To do transdisciplinary research, appropriate methods for supporting joint problem identification, problem analysis, and strategy development have to be identified. Modeling is an appropriate and widely used method in environmental sciences and management, as knowledge about the complex human-environment system has to be integrated. To truly support transdisciplinary research, a relatively simple modeling approach is required. The approach should be able to (1) represent and integrate knowledge from diverse disciplines and spheres, (2) explicitly support the inclusion of stakeholder knowledge and perspectives, and (3) take into account the uncertainty of knowledge.

Bayesian networks (BNs) fulfill these requirements. BNs have already been used in support of environmental management, in a few cases also in participatory settings where stakeholders were involved in the modeling process beyond the discussion of modeling results. In their literature review on the application of BNs in environmental modeling for the time period 1990-2010, Aguilera, A. Fernández, R. Fernández, Rumí and Salmerón (2011) [55] found that less than 5% of all identified applications of BNs were in the field of environmental sciences. Uusitalo (2007) [56] reviewed the advantages as well as the challenges of using BNs in environmental modeling and summarized the state of the art of applying BNs. She concluded that BNs are "a useful addition to the toolkit of environmental scientists, especially if their work is related to environmental management". Introducing a special issue on BNs in environmental and resource management, Barton et al. (2012) [57] showed how BN modeling can be adapted to the structure of the problem of interest and stated that BNs have been most widely used in support of mid-to-long-term strategic decision-making at the scale of e.g. catchments or habitats. Castelletti and Soncini-Sessa (2007) [58] considered the integration of BN modeling into a participatory planning process and discussed the specific limitations of BNs in water resources management. Comprehensive guidelines on the application of BNs in support of participatory planning were provided by Cain (2001) [58], Bromley (2005) [60] and Pollino and Henderson (2010) [61].

In this review, we aim at synthesizing the knowledge about application and applicability of BNs as a participatory modeling tool in transdisciplinary research. We wish to provide a solid knowledge basis for researchers (with experience in either BNs or participatory methods) and practitioners who consider using BNs in participatory processes. In section 2, we give a short introduction into BNs. In section 3, we review literature on the application of BNs as a participatory modeling approach in support of environmental management. We provide recommendations on how to apply BNs as a participatory modeling tool in section 4. This is followed, in section 5, by summarizing strengths and limitations of BNs. Finally, we draw conclusions.

3.3 Bayesian Networks

A BN is a model of a selected real system that represents the system's components and relations in the form of a probabilistic causal network. The terms Bayesian Network, Bayesian Belief Network, belief networks and Bayes net are synonyms [62, 63].

3.3.1 Elements of Bayesian Networks

BNs consist of three elements [59]: (1) System variables referred to as nodes and visualized as boxes, (2) Causal relationships between these nodes visualized as directed links which point from cause to effect, and (3) A set of (conditional) probabilities, for each node, defining the strength of the causal relationships. Figure 3-1 is an example of a simple BN (network structure and states of the variables) that models the decision of a reviewer to accept or reject a scientific paper. The diagram indicates that the system variable "Reviewer's decision" is influenced by the "Quality of the paper" as well as by the "Weather conditions" which influence the reviewer's mood and thus decision. The influences are depicted as causal links. In this case, the nodes "Quality of the paper" and "Weather conditions" are the parent nodes of "Reviewer's decision", while "Reviewer's decision" is the child node of the two influencing nodes.

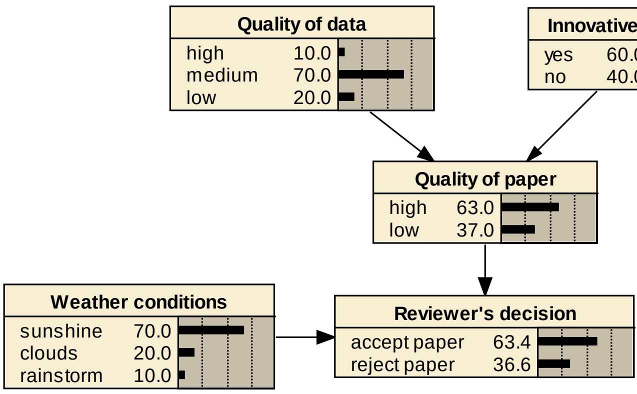

Figure 3-1: A simple Bayesian Network "Reviewer´s decision".

Nodes without parent nodes, such as "Quality of data", "Innovative approach", and "Weather conditions", are called root nodes. Nodes without child nodes, such as "Reviewer's decision", are called leaf nodes. Root nodes represent the input variables, while leaf nodes constitute the output variables of the BN [58].

Variables (i.e. nodes) can be either continuous or discrete (as in Figure 3-1), and in most BN applications, discrete variables are described by a limited number of discrete states (e.g. three in the cases of "Weather conditions"). States for discrete nodes can either be (1) labels, e.g. "low, high", (2) numbers, (3) intervals, or (4) in Boolean form (e.g. "yes, no") [60]. The states must encompass all possible conditions and must be mutually exclusive. As BNs are directed acyclic graphs, feedback loops are not possible in the networks.

For each child node, conditional probability tables (CPTs) need to be defined. A CPT expresses the probability for the states of a child node, given the states of its parent nodes. The rows of the CPT can be read as "if-then-sentences". In our example, the CPT of "Reviewer's decision" reveals that "If the quality of the paper is high and the sun is shining, then the paper will be accepted with a probability of 95%" (Figure 3-2). The CPT shows the strengths of the causal relationships, with the "Quality of the paper" having a much stronger impact on the decision than the "Weather conditions".

Quality of paper	Weather conditions	accept paper	reject paper
high	sunshine	95	5
high	clouds	90	10
high	rainstorm	85	15
low	sunshine	15	85
low	clouds	10	90
low	rainstorm	5	95

Figure 3-2: Conditional probability table of node "Reviewer's decision".

Root nodes are quantified by unconditional probability tables which can represent observations, scenarios, or potential actions such as management interventions [60]. If root nodes are used to represent different scenarios of the future, the states can also be described with respect to the current conditions, for example with labels "lower than today, like today, higher than today" [59].

3.3.2 Entering data into the network

Both the CPTs and the network structure can be automatically learned from data. In problem fields typically assessed by transdisciplinary research, however, not enough data is available for automatic generation of the network structure. The network structure, including the definition of the states, is developed together with stakeholders or based on information gained from literature. In the next step, unconditional probability tables of the root nodes and the CPTs are developed using data obtained from different sources. These include stakeholder/expert knowledge, literature information, observational or statistical data, or output from more detailed numerical models (e.g. [64]).

3.3.3 Top-down and bottom-up modeling

Bayesian networks can either be used "top-down" for predictive purposes or "bottom-up" for diagnostic purposes [58]. Top-down modeling or downward propagation refers to the calculation of the probability distributions of all child nodes in response to the probability distributions of the root nodes, as a function of the network structure and the CPTs. Referring to Figure 1, the probability distributions for “Quality of paper” and “Reviewer’s decision” were calculated by the BN modeling software, while the probability distributions of the three root nodes had been set before. If it is known, for example, that the sun is shining during the review process, the probability of “sunshine” of the root node “Weather conditions” can be set to 1 or 100% and a higher probability for the acceptance of the paper would be calculated, compared to the probality shown in Figure 1. For top-down modeling, the BN modeling software uses the fundamental rule of probability and a joint probability calculation to update the probability distributions for all other nodes [61, 65]. Top-down modeling is appropriate for impact and scenario analyses, where the BN computes the impact of certain boundary conditions and management decisions on the variables that are planned to be optimized. These boundary conditions and management decisions are often represented by setting the probability of a certain state of a root node to 100% and their impact is represented by the probability distribution of the child nodes, in particular of the leaf nodes.

Bottom-up modeling or upward propagation refers to the application of the Bayes’ rule to update the probability distributions of the parent nodes after a finding that is based on observations was entered for a leaf node or any other child node. Bottom-up modeling is applied for diagnostic purposes, e.g. to assess the likely reasons for an observed environmental pollution. Bottom-up modeling is not equivalent to optimization, i.e. the updated probability distributions of the root nodes cannot be interpreted in terms of decisions that would lead to the observed finding or any desired state of the leaf node. Thus, when applying BNs as participatory modeling tools, they are always used top-down because participatory processes typically aim at a joint strategy development based on impact and scenario analyses.

3.3.4 Bayesian Network software

BN modeling is supported by a large number of software packages. Fenton and Neil (2007) [66] compiled a useful list of commercial, open source, and free software tools. Uusitalo (2007) compared various software packages for building BNs in more detail [56]. In the field of environmental modeling, Netica and Hugin are most frequently used [55].

3.4 Recent applications on participatory Bayesian Network modeling in environmental management

To review recent applications of BNs in environmental management within a participatory process, we conducted a keyword search for the terms "Bayesian Network" or "Bayesian Belief Network" in the ISI Web of Knowledge, for the period 2001-2011. We included twelve subject areas (Agriculture, Biodiversity Conservation, Ecology, Environmental Sciences, Energy Fuels, Fisheries, Forestry, Geography, Marine Freshwater Biology, Plant Science, Toxicology, and Water Resources) that are related to environmental management. Publications from outside the field of environmental management were excluded.

The resulting 182 publications were categorized and assessed according to the degree of stakeholder or expert involvement in the BN modeling processes. For this analysis, experts were not distinguished from stakeholders. Categorization was done based on the seven stages of BN modeling process as described by Bromley (2005) [60]: (1) Defining problem, context, and stakeholder engagement; (2) Identifying variables, potential actions/scenarios, and indicators to describe the system; (3) Designing the pilot network; (4) Collecting data from all available sources including stakeholders; (5) Defining states of all variables; (6) Constructing CPTs; and (7) Checking network consistency, collecting feedback from stakeholders, and making the final decision. Less than one third of the publications included expert involvement in at least one of the seven steps (Table 3-1).

Table 3-1: Number of publications on BNs in environmental management with different degrees of stakeholder involvement according to Bromley (2005) [60] (ISI Web of Science 2001-2011).

Category	**Category definition**	**Number of publications 2001 - 2011**
P_0	BN generation without stakeholder or scientific expert involvement	123
P_{1-7}	BN generation with stakeholder or scientific expert involvement in at least one stage of BN modeling process	59

Figure 3-3 shows the trend of publications on BN generation with (P1-7) and without (P0) stakeholder participation. The total number of publications has increased significantly since 2007, while the proportion of publications on participatory BN modeling remained nearly constant.

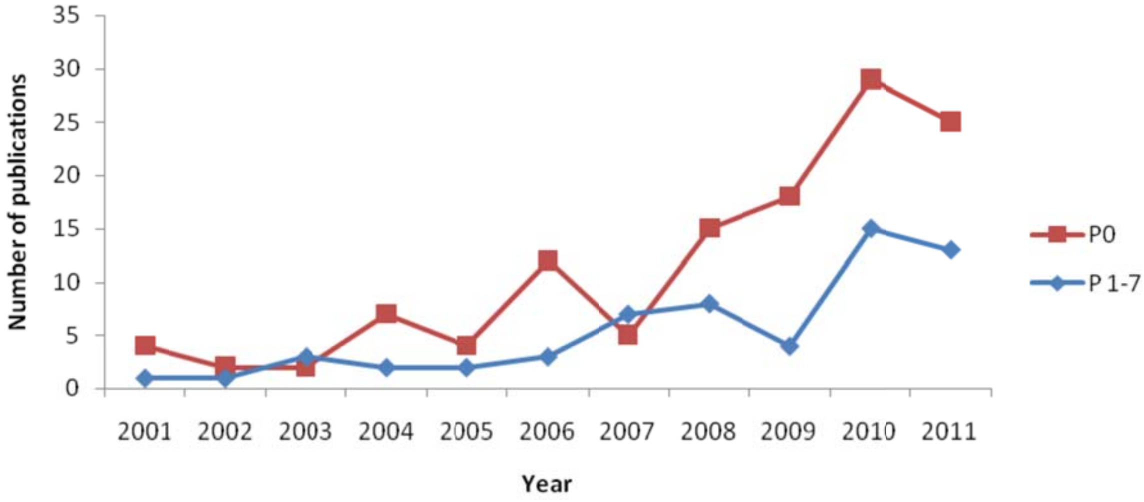

Figure 3-3: Publications on BN modeling in environmental management from 2001 – 2011, without participation (P_0) and with stakeholder participation ($P_{1\text{-}7}$) (ISI Web of Science; keywords: "Bayesian Network" or "Bayesian Belief Network").

Out of the 59 case studies with stakeholder participation, 30 cases describe stakeholder involvement in at least two stages according to Bromley (2005) [60] (Table 3-3). The following questions guided our assessment of the identified 30 case studies:

- In which fields of environmental management was BN modeling conducted using a participatory approach?
- How many stakeholders were involved in the participatory modeling process?
- What kinds of stakeholders were involved?
- In which stages of BN modeling were the stakeholders involved?
- How were stakeholders involved?
- What was the information basis used for the construction of CPTs?
- How was the participatory process designed?
- Did stakeholders use the BN as a decision support system (DSS) in practice?

3.4.1 Application of participatory Bayesian Network modeling in environmental management

Participatory BN modeling was mainly applied in water management and conservation management fields, with 15 and 13 cases, respectively (Table 3-3). In the field of water management, BN modeling was motivated by the requirement for stakeholder involvement stipulated in transnational and national water regulations [67].

3.4.2 Number and type of stakeholders involved

The average number for stakeholders involved in participatory BN modeling was about 10, with a minimum of two stakeholders [68] and a maximum of 23 stakeholders [67]. In four of the participatory modeling processes, only scientific experts were involved [69–72]. In one case, this type of stakeholders made it possible to do a review of the developed model by writing a joint publication [70].

In 26 case studies, stakeholder participation went beyond the involvement of scientific experts to take into account the perspectives of stakeholders outside academia. Except in one case ([63], see section 4.1), citizens were not involved. In the case of Borsuk, Stow & Reckhow (2004), citizens′ perceptions as derived from interviews into the BN were considered within the participatory modeling process [73].

3.4.3 Stages of Bayesian Network modeling process that stakeholders were involved in

In 17 of the case studies, stakeholders were involved in the three stages of identification of variables, potential actions/scenarios and indicators (stage 2), and the construction of the pilot network (stage 3) as well as CPTs (stage 6) (Table 3-3). In only seven case studies, stakeholders provided data (stage 4), and in only eight cases stakeholders were consulted to check the consistency of the BN model (stage 7) (Figure 3-4). None of the case studies reported the involvement of stakeholders in all seven stages (Table 3-3).

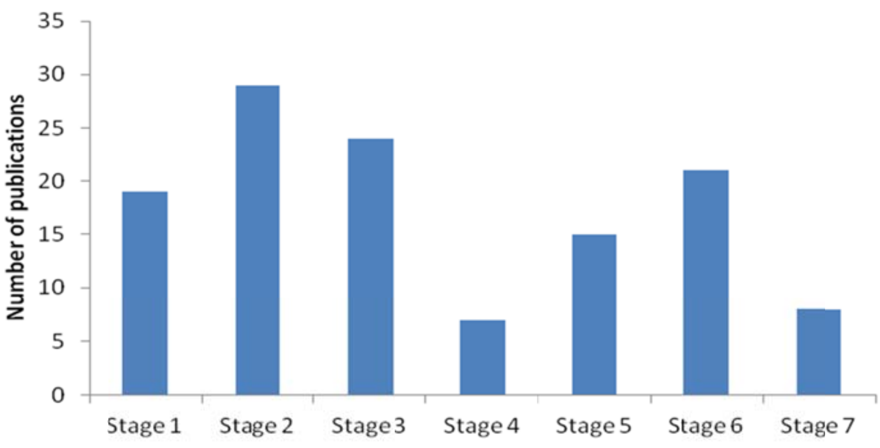

Figure 3-4: Number of case studies with stakeholder involvement in different stages of participatory BN modeling.

The stages are: (1) Defining the problem, context and stakeholder engagement; (2) Identifying variables, potential actions/scenarios and indicators to describe the system; (3) Designing the pilot network; (4) Collecting data from all available sources including stakeholders; (5) Defining states of all variables; (6) Constructing CPTs; (7) Checking network consistency, collecting feedback from stakeholders and making a final decision [60].

3.4.4 Forms of stakeholder involvement

There are six case studies in which different stakeholder groups were involved separately [63, 68, 74–77]. Penman et al. (2011) [68] pointed out that they separated the stakeholders for the workshops to record differing opinions and experiences of each stakeholder. In most of those case studies, different BNs were built. Model-averaging was proposed by Hammond and O´Brien (2001) [76] as a method to integrate different BNs. Chan et al. (2010) [74] described how to merge the conceptual models of three groups (government, NGO and community) into one stakeholder diagram.

3.4.5 Information basis for the generation of CPTs

Most case studies used a combination of different input data to fill in the CPTs (Table 3-3). Input included outputs of numerical models, stakeholder knowledge, statistical and observational data, and literature findings. In six case studies in the fields of water, conservation and fishery management, the CPTs were derived from stakeholder knowledge only. In ten cases, information from more detailed numerical models was integrated into the BN (Table 3-3). Peterson et al. (2008) [71] developed in total three BNs with the same network structure but with different CPTs, with one reflecting only expert knowledge. They compared the performance of the models and concluded that the outcomes of the three BNs were consistent.

3.4.6 Time and effort required

Most case studies do not provide information about the duration of their participatory processes or the frequency of meetings with stakeholders. Information available ranges from one six-hour workshop [74] to three workshops [63], and to four 1- to 2-day meetings for the basic conceptualization of the BN [78] (Table 3-2). The most common duration (from the first to the last workshop) of a participatory process was from one [67] to one and a half years [63].

Table 3-2: Design of participatory process (PP) in three case studies.

Case study and field of application	PP period (from first to last workshop)	Number of workshops in the PP	Duration of the workshops
Cain et al. (2003), water management [74]	24.09.1999 - 02.10.1999	3 in total (1 workshop with government organizations, 1 workshop with farmers upstream, 1 workshop with farmers downstream)	workshop 1: 6 h, workshop 2 & 3: 4,5 h
Henriksen et al. (2007), water management [63]	October 2002 - March 2004	10 in total (5 workshops with professional group, 5 workshops with citizen group)	workshop 1 with professional group: 1 day
Lynam et al. (2010), water management [78]	June 2007 - October 2007	4	each 1-2 days

In a feasibility study, Lerner, Kumar, Holzkämper, Surridge, and Harris (2011) [79] estimated the manpower resource required for building an integrated catchment management model in a participatory manner. The BN model was proposed as a meta-model for a more complex systems model, to be used by decision-makers. They estimated that 20 person-months of the project team would be necessary for construction, validation, and testing of the BN. Additionally, each stakeholder would have to spend two days, and each domain expert five days, for validation and testing of the BN model. Much more time was estimated to determine, in the beginning of the process, the scope of the model and to develop a conceptual model [77].

BNs used as DSS

Most of the studies proposed that BNs have the potential to function as a decision support system (DSS) in practice. Only three case studies [67, 74, 80] explicitly mentioned the successful implementation of BNs as DSS (Table 3-3). Ticehurst, Newham, Rissik, Letcher and Jakeman (2007) [81] developed a DSS that was derived from a BN, to evaluate the sustainability of a coastal lake in Australia. They provided training for DSS application to potential users. The low use of BNs as DSS is not specific to BNs but is true for other model-based tools, too; this is due to many reasons [82, 83].

Table 3-3: Applications of BNs for participatory modeling in environmental management, 2001-2011. Refer to section 3 regarding the stages of stakeholder involvement.

Case study	**Field of application**	**Stages with stakeholder involvement according to Bromley (2005)**	**Derivation of conditional probability tables**	**Using the BN as DSS in practice**
Ames et al. (2005)[1] [84]	water management	1, 6	data, stakeholder knowledge	unknown
Bashari, Smith, & Bosch (2008) [85]	conservation Management	2, 5, 6, 7	data, stakeholder knowledge	unknown
Borsuk, Stow, & Reckhow (2004) [73]	water management	2,6	data, stakeholder knowledge, literature	unknown
Cain et al. (2003) [74]	water management	1, 2, 3, 5, 6	stakeholder knowledge	yes
Carmona, Varela-Ortega, & Bromley (2011) [86]	water management	2, 3, 5, 6, 7	numerical models, data, stakeholder knowledge, literature	unknown
Chan et al. (2010) [75]	water management	1, 2, 3, 4	numerical models, data, stakeholder knowledge, literature	unknown
Cyr et al. (2010) [69]	conservation management	2, 3, 5	data	unknown
Haapasaari, Michielsens, Karjalainen, Reinikainen, & Kuikka (2007) [87]	fishery management	1, 2, 3, 5	stakeholder knowledge	no
Hamilton, Fielding, Chiffings, Hart, & Johnstone (2007) [88]	water management	1, 2, 3, 5, 6	numerical models, data, stakeholder knowledge	unknown
Hammond & O`Brien (2001)[1] [76]	fishery management	2, 3	unknown	no
Helle, Lecklin, Jolma, & Kuikka (2011) [89]	conservation management	2, 3, 6	numerical models, data, stakeholder knowledge, literature	unknown
Henriksen et al. (2007)[1] [63]	water management	1, 2, 3, 4, 5, 6	data, stakeholder knowledge, literature	unknown
Inman et al. (2011) [80]	water management	1, 2. 3, 4, 7	stakeholder knowledge, literature	yes
Johnson et al. (2010) [77]	conservation management	1, 2, 3, 5, 6, 7	Stakeholder knowledge	unknown
Kragt et al. (2011)[1] [90]	water management	2, 5	numerical models, data, stakeholder knowledge	no

Table 3-3: Applications of BNs for participatory modeling in environmental management, 2001-2011. Refer to section 3 regarding the stages of stakeholder involvement (continued).

Case study	Field of application	Stages with stake-holder involvement according to Bromley (2005)	Derivation of conditional probability tables	Using the BN as DSS in practice
Lecklin, Ryömä, & Kuikka (2011) [91]	conservation management	2, 3, 6	stakeholder knowledge, literature	unknown
Lerner et al. (2011)[2] [79]	water management	1, 2, 3	numerical models, data, stakeholder knowledge	unknown
Lynam et al. (2010) [78]	water management	2, 3, 6	numerical models, data, literature	unknown
Marcot et al.(2006) [70]	conservation management	1, 2, 3, 5, 6, 7	data, stakeholder knowledge	unknown
Martínez-Santos et al. (2010)[2] [92]	water management	1, 2, 3, 4, 5, 6	numerical models, data, stakeholder knowledge, literature	no
McCloskey, Lilieholm, & Cronan (2011) [93]	conservation management	2, 5, 6	stakeholder knowledge	unknown
Molina et al. (2011) [67]	water management	2, 3, 4, 6, 7	data, stakeholder knowledge, literature	yes
Penman et al. (2011)[1] [68]	conservation management	1, 2, 3, 4, 5, 6	numerical models, data, stakeholder knowledge	unknown
Peterson et al. (2008) [71]	conservation management	1, 2, 3, 6	numerical models, data, stakeholder knowledge	unknown
Pollino et al. (2007) [94]	conservation management	1, 2, 3, 5, 6, 7	data, stakeholder knowledge	unknown
Pollino, White, & Hart (2007) [95]	conservation management	1, 2, 3, 6	data, stakeholder knowledge, literature	unknown
Ticehurst et al. (2007) [81]	conservation management	1,2,3	data, stakeholder knowledge, literature	unknown
Uusitalo, Kuikka, & Romakkaniemi (2005) [72]	conservation management	1,2,3,6	stakeholder knowledge	unknown
Wang, Robertson, & Haines (2009) [96]	water management	1,2,5	stakeholder knowledge, literature	unknown
Zorrilla et al. (2010)[2] [97]	water management	1, 2, 3, 4, 6, 7	stakeholder knowledge	unknown

[1]Study describes optimization with decision nodes; [2]Study includes formal evaluation of the application of participatory BN.

3.5 Recommendations for the application of BNs in participatory processes

Mainly based on the 30 reviewed case studies and the three guidelines for participatory BN modeling [59–61], we now formulate recommendations for participatory BN modeling using the seven stage structure proposed by Bromley (2005) [60]. The seven stages and the corresponding steps of BN construction and stakeholder involvement are summarized in Table 3-4. We focus on five of the seven stages of the process, propose an evaluation of participatory BN modeling and give general recommendations for the whole process.

3.5.1 Stage 1 – Defining the problem, the context and the stakeholder engagement

In the beginning of the process, participants' expectations should be elicited and openly addressed in order to avoid misunderstandings regarding aims and scopes of a project [75]. Henriksen et al. (2007) [63] suggested formulating stakeholder involvement plans to make the participatory process more transparent regarding time schedule, expectations, and "rules of the game" (Table 3-3).

It is important to include a broad range of interest groups in the BN construction in order to integrate different types of knowledge and problem perspectives [81]. If BNs are planned to be used as a DSS, Cain et al. (2003) [74] suggested the formation of a "core group" of policy makers which sufficiently represent all disciplines (governmental departments). This group should be trained in the application of the BNs and asked to take adequate time to construct a BN in an iterative process and in consultation with external experts. Henriksen et al. (2007) [63] pointed out that a T-organization, i.e. a temporary organisation of representatives from the water authority, experts, stakeholders and citizens, should be formed. In the T-organization, the water authority leads the process and makes the ultimate decisions. At the early stage of the process a "leadership" group identified other stakeholders, initiated the process and developed a first BN to inform other stakeholders about the aim of the process. Later, a "professional" stakeholder group was established out of ten institutions that were involved in groundwater management, as well as an independent "local citizens" group of nine citizens from the area of concern which organized a public meeting of 100 citizens at the local community house. The idea was to take into account the different starting points and to let the "local citizens" group develop their own position without being influenced by the "professional" stakeholder group. The "local citizens" group contributed knowledge to the BN, took part in the evaluation of the BN results and wrote three newsletters to inform the local community.

Table 3-4:. Stages and steps of participatory BN construction with stakeholder involvement according to Bromley (2005) [60].

	Definition of stages	Steps in BN construction	Stakeholder involvement
1	define the problem, the context and stakeholder engagement	define objectives	identify and select stakeholders
		delineate geographical area of interest	analyze stakeholder interest, world perception
		define soc. and econom. boundaries	agree on roles and responsibilities
		identify time horizon	agree on stakeholder involvement plan
2	identify variables, potential actions and indicators to describe the system	list all factors to be addressed	list stakeholder concerns
		identify key indicators	stakeholders to suggest important indicators
		identify potential actions/scenarios	suggest list of possible actions/scenarios
		identify data sources	stakeholders to identify data sources
3	design a pilot causal network	define input variables and links for the network	stakeholder interview: receive comments on the design of the initial network
		design causal network,minimizing the size of the network and of the required CPTs)	demonstration including CPTs to illustrate power of networks
		check consistency, logic & focus of network	arrange system of dissemination to stakeholders and or general public
4	collect data from all available sources including stakeholders	collect data for each variable and causal link	individual stakeholder interview: collect data from individual stakeholders
		analyze data	-
		revise network structure based on data availability	-
5	define states for all variables	define states for all variables	stakeholder interview: input for stakeholders for states
6	construct CPTs	manual entry of CPTs	individual stakeholder interview: obtain stakeholder opinion
		automatic learning techniques to generate CPTs	-
		review network and amend as necessary	individual stakeholder interview: obtain stakeholder opinion
7	check network consistency, collect feedback from stakeholders and make final decision	check consistency of network: does it make sense	-
		evaluate feedback from stakeholder and incorporate if necessary	stakeholder interview: feedback from stakeholders an review of network
		add decision nodes if required	-
		evaluate/modify/adopt network/ sensitivity analysis	-
		implement BN in DSS if required	-
		alternative options/negotiation/decision	decision/reporting comments from stakeholders

3.5.2 Stage 2 – Identifying variables, potential actions/scenarios and indicators to describe the system

It is helpful to categorize the variables identified by the stakeholders according to their function in the BN. Cain (2001) [59] distinguished between: (1) Objectives: variables that are to be influenced through management interventions, the key output of BN. (2) Interventions: management options to achieve the objectives. (3) Intermediate variables: factors that connect objectives and interventions. (4) Controlling factors:

control the environmental system, but cannot be influenced on considered scale (e.g. rainfall, population growth). (5) Implementing factors: influence the interventions. (6) Additional impacts: variables in addition to objectives that are affected inadvertently by interventions (Figure 3-5). Molina et al. (2011) [67] proposed five similar categories.

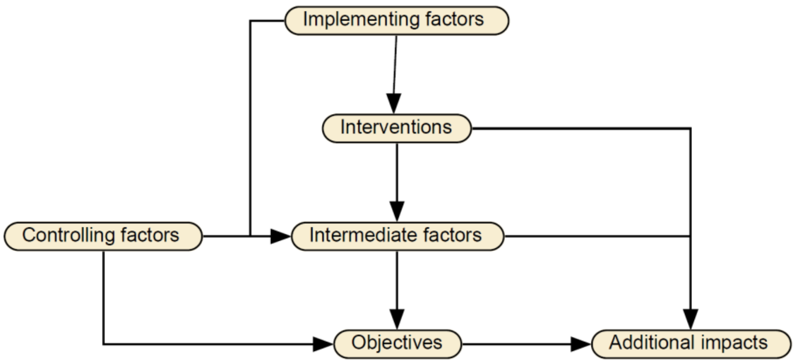

Figure 3-5: Conceptual model for categorizing variables [59].

The identification of variables should aim at designing a parsimonious model that captures the most relevant processes and causal relations. Therefore, after a broad range of potentially relevant variables has been defined, variables should be reviewed with regard to their relevance but also the possibility of quantifying conditional probabilities. To this end, it is useful to focus, as much as possible, on variables that are controllable or observable at the considered scale [73].

3.5.3 Stage 3 – Designing a pilot causal network

Marcot et al. (2006) [70] advised to start with simpler causal networks when introducing BNs to non-modelers and recommended a thorough documentation of source material and single steps of network construction in order to avoid "battles of the experts" afterwards. Structuring the whole BN as interacting sub-networks simplifies the representation of a complex system [95]. For the construction of the sub-networks the stakeholders were divided according to their expertise in the fields covered by the sub-networks [77]. The first version of a causal network, when developed with stakeholders, is likely to be overly complex, as each participant might want to see the part of the problem particularly well included that s/he is most concerned about; therefore, some simplification is required before CPTs are constructed [73].

3.5.4 Stage 6 – Construct CPTs

The question "What is the probability that variable A takes state X given information Y?" [94] can be used to elicit stakeholder knowledge for generating CPTs. It is prefer-able to consult more than one stakeholder for constructing a CPT, to increase the trust in the BN results.

In case of differing estimations of CPTs, CPTs can be averaged [71]. If the differences reflect strongly diverging views, the different CPTs should be included explicitly in the BNs. To make two different perspectives on the impact of pesticide application on groundwater quality explicit, Henriksen et al. (2007) [63] added an additional variable with opposing states to the BN such that the results of both perspectives could be compared. In Netica, it is also possible to integrate stakeholders´ confidence in their probabilistic estimates. This kind of weighting helps to combine data and stakeholder knowledge for CPT generation [94].

3.5.5 Stage 7 – Check network consistency, collect feedback from stakeholders and make final decision

Once the BN has been constructed, it should be tested and reviewed for consistency by an experienced BN modeler. In addition, stakeholders must be involved in testing the BNs to make them credible, either as a group within a workshop or individually [63, 68, 97](see also Table 3-4).

After BN validation, the BN can calculate the effects of various scenarios [86] or management alternatives (Table 3-4). This may require the development of qualitative scenarios [99]. To this end, states of root nodes need to be set. The changes in the probability distribution of the leaf node indicate the impact of each scenario. It might be difficult to interpret these calculated outputs. One possibility is to include decision and utility nodes into the BN to make impacts of several management actions comparable. Decision and utility nodes have the advantage to be associated with deterministic costs and benefits [80].

3.5.6 Evaluating the success of participatory BN modeling

Given the limited experience with participatory BN modeling, an evaluation of each process is paramount to increase the positive outcomes of participatory BN modeling processes. Unfortunately, very little information on the evaluation of participatory BN modeling processes is available in the literature. Henriksen and Barlebo (2008) [63] did an ex-post evaluation of the participatory BN modeling process described in, for which they performed in-depth interviews with two involved water managers [100]. Zorrilla et al. (2010) [97] and Inman et al. (2011) [80] developed criteria for the evaluation of participatory BN modeling and asked workshop participants to fill out the questionnaires at the end of their workshop. Martínez-Santos, Henriksen, Zorrilla and Martínez-Alfaro (2010) [92] evaluated BNs by comparing their experiences with participatory BN modeling to experiences with participatory modeling with a groundwater flow model, and found that the modeling approaches are complementary. Questions that can lead through the evaluation are e.g. "In which ways can BNs promote environmental management and allow the management to progress in the face of complexity and uncertainty?", "How do BNs support development of a shared system understanding and provide a structured approach of learning?", and "How can BNs support the transition from the actual traditional management into more adaptive management that is able to deal with changing conditions?" [100]. Criteria that should be included in the evaluation are: (1) Structured process to deal with complex planning; (2) Integration of knowledge from diverse sectors; (3) Visual presentation of cross-benefits; (4) Description and decrease of uncertainty in prognosis; (5) Limitation of complexity; (6) Support communication and social learning; (7) Link of research to policy; (8) Identification of lack of knowledge for integration [79, 92, 100].

If the aim of the modeling process is to build a decision support tool for environmental planning, the effectiveness of this decision support tool can be evaluated in addition. Evaluation criteria for this approach are e.g. (1) Organizational receptivity, (2) Reliance on decisions, (3) Technical suitability, (4) Transparency, (5) Learning, (6) Ease of use, or (7) Decision stress [80].

3.5.7 General recommendations for participatory BN-modeling

Building of trust is essential for successful participatory modeling with BNs [75]. Therefore it is necessary to create a respectful atmosphere that enables open discussions. It may be beneficial to involve a professional facilitator to overcome communication problems due to different disciplinary backgrounds [63, 90]. In addition, a professional facilitator can handle dominant personalities that might bias results [68]. Nevertheless, researchers who are experienced in the design of participatory processes and in modeling, are better prepared to guide the participatory modeling process itself.

As most stakeholders and experts may not be familiar with probabilistic reasoning, it is useful to integrate training on Bayesian probabilities and BNs. Hands-on training for stakeholders is necessary to create ownership and trust, and in particular to apply BNs as decision support tools in practice [100]. Enabling stakeholders to experiment with BNs may lead to more dynamic, interactive and transparent BN exercises [100], but time constraints of stakeholder involvement may prohibit a more in-depth involvement of stakeholders with BNs. It is desirable to couple BN modeling with Geographical Information Systems to better visualize the spatial dimensions of the modeling results as these are typically of high relevance in environmental management [100].

3.6 Strengths and limitations of Bayesian Networks as participatory modeling tool

Literature reviews [55, 56], guidelines [59, 60] and various case studies (e.g. [63, 97]) evaluated the strengths and limitations of Bayesian networks for environmental modeling and management. Here, we focus on their strengths and limitations for participatory modeling.

3.6.1 Strengths

- Integration of knowledge from various disciplines and spheres: Knowledge from a wide range of disciplines and spheres can be integrated (e.g. [63]) because a BN, with its causal network, allows relating very different variables to each other. The discrete states of the variables allow constructing rather simple probabilistic descriptions of the relation between two variables, which is warranted in case of models which include diverse variables the relation of which is rather uncertain. However, the BN can be made more complex if appropriate. BNs can also help to identify knowledge gaps. Haapasaari and Karjalainen (2010) [101] concluded that the probabilistic language of BNs enabled the integration of social, natural and economic perspectives which in turn facilitated the communication within their multi-disciplinary research group.
- Explicit inclusion of stakeholder knowledge and perspectives: Stakeholders contribute, in a first step, to the construction of the causal net, which allows articulation of their specific knowledge and views on the environmental system under consideration. Regarding the setting of probabilities, the specific Bayesian perspective on probability allows integrating subjective beliefs of stakeholders but also of experts and citizens [74, 78, 86].
- Explicit consideration of uncertainty: The probabilistic presentation of knowledge in BNs allows considering uncertainty (which is mostly large in most environmental problems) throughout the analysis process in a transparent way. In addition, it prevents overconfidence in the response to management interventions [56].
- Variety of possible input data: The wide range of input data is a major strength of BNs. Input data, in particular conditional probability tables, may be derived from subjective beliefs, direct measurements or output data from more detailed models, or from a combination of these data sources [60]. In case of appropriate measurements, conditional probability tables can be automatically learnt from data by BN software [68]. This variety of

input data helps to overcome data scarcity. Bayesian networks can also perform analyses with relatively small and incomplete data sets [84].

- Transparency: With BNs it is possible to clearly represent expertise, uncertain knowledge or assumptions in a transparent way. Based on four case studies, Bromley (2005) [60] emphasized that decisions which have been supported by a participatory BN modeling process are transparent. BNs therefore provide the opportunity to make environmental decision-making more acceptable to the public.
- Short run times: Together with the graphical interface, very short run times of BNs allow users to play with the model and to quickly quantify the impact of certain decisions on the probability distribution of child nodes.
- Communication and learning: Evaluations of BNs as a participatory tool revealed that BNs have the potential to facilitate communication and learning among different stakeholders [78, 97]. The BN diagram (Figure 3-1) visualizes how systems function, thus facilitating stakeholder learning [60]. Fast run-times of BN models also allow quick recalculations within a stakeholder workshop, thus allowing the participants to learn from modeling results as a group. Learning among stakeholders also includes understanding each other's concerns. BNs are useful for discussions between different disciplines and stakeholder groups [63, 96]. They can provide a focus for the stakeholder dialogue [60] and even help to structure the overall participatory process [97].
- The availability of user-friendly software packages makes the application of BNs also accessible to non-specialists.

3.6.2 Limitations

- Limited representation of spatial variability, temporal dynamics and feedbacks: As discussed by Pollino and Henderson (2010) [61], static spatial variability (e.g. that different location has different properties) can easily be taken into account by parent nodes that have specific locations as states. Modeling spatial relations and their impact, however, can only be done in a very restrictive way. Temporal dynamics can be represented by combining various BNs to dynamic BNs but the number of time steps is very limited due to excessive computing times [61, 64, 66]. Castelletti and Soncini-Sessa (2007) [58] therefore concluded that BNs are not suitable for highly dynamic problems which are often encountered in water resources management. As BNs are acyclic graphs, feedbacks cannot be modeled in a static BN. But if the feedback occurs at the same time-scale as that of the time-scale of a dynamic BN, a feedback loop can be represented [61].

- Difficulty to elicit conditional probabilities: Populating CPTs is demanding for stakeholders and scientific experts. Eliciting knowledge from scientific experts in a probabilistic form may be difficult if they are not familiar with probabilistic thinking and data analyses. Uusitalo (2007) [56] surmised that scientific experts usually working with observational data may have trouble formulating beliefs without relying on data. Scientific experts usually working with classical statistical analyses may have problems expressing their knowledge in a probabilistic way [56]. In addition, people are prone to overconfidence when it comes to probabilistic estimations [101]. Therefore, it is the modeler's responsibility to carefully interpret probability values in CPTs that are very close to zero or one.
- Reliability of expert beliefs and BN modeling results: Quantitative (deterministic or probabilistic) knowledge about causal relations is generally poor for complex human-environment systems that are often of interest in strategic environmental management. In this case, the CPTs are highly uncertain and possibly inaccurate. Even though the stakeholder group agrees on the validity of a jointly developed BN, the computed probability distributions may be incorrect. Keith (1996) [102] pointed out that the number of experts sharing one belief is not necessarily proportional of that belief being correct.
- Cognitive difficulties with probabilities: The probabilistic representation of knowledge is challenging for participatory modeling. Many people have cognitive difficulties to understand probabilities, especially to grasp conditional probabilities [103]. Therefore the network structure needs to be very simple, and the number states should be rather small [66]. The fact that most stakeholders are more familiar with deterministic model results than probability distributions might also constrain the understanding of the model output [97].
- Lack of precision of BN models and results: The use of a small number of states for discrete variables, such as "low, medium, high" necessarily leads to an imprecise and vague representation of the system under consideration, and to results that may be difficult to interpret. This can only be overcome to a certain extent by defining numerical boundaries to terms like "low", e.g. related to a certain water quality norm. To avoid this lack of precision, Borsuk, Schweizer and Reichert (2012) [104] chose to use contin-

uous variables but this is only possible in case of well-researched causal relationships.

3.7 Conclusions

The number of participatory modeling applications of BNs in environmental management is still small. Nevertheless, the 30 reviewed case studies have shown that BN modeling can be successfully applied within a participative process. Together with the guidelines of Cain (2001) [59], Bromley (2005) [60] and Pollino and Henderson (2010) [61], the case studies form a very useful information base for new projects that wish to support transdisciplinary knowledge integration by participatory BN modeling .

Many features make BNs particularly suitable for supporting the identification of sustainable management strategies in problem fields related to complex human-environment systems. Nevertheless, a thorough contemplation of the balance of strengths and limitations of BNs in the specific problem context is recommended before BN modeling is selected as a participatory modeling approach. To allow for a better representation and visualization of spatial heterogeneity, which is required for supporting land and water management, coupling of BNs to Geographical Information Systems is recommended. To at least partially overcome the limitations of BNs related to the lack of precision and accuracy, BN models can be combined with more detailed models. While the BN serves to represent the total human-environment system of interest, more detailed models for sub-domains for which better quantitative knowledge exists are coupled to certain BN nodes. Depending on the location of the coupling nodes within the BN, the detailed model can be used to construct a CPT, or the probability distribution computed by a BN can serve to define the input to a detailed model. For example, the BN may be used to quantify the probability distribution of pollutant emissions under certain scenarios of external driving forces and management options, while the computed emissions scenarios are used, by a soil and groundwater transport model, to compute pollutant concentrations at a drinking water well. With such a coupling of BN and detailed model, the output of the detailed model is more precise then the results of the BN could be, while it is more relevant than it could be without the emissions scenarios derived by the BN.

We conclude that participatory modeling of human-environment systems with BNs has the potential to become a core method of transdisciplinary research and knowledge integration in environmental management. We therefore recommend that environmental scientific experts and managers get acquainted with BNs at least on a general level, and consider their use in transdisciplinary and participatory processes.

4

Causal networks and scenarios: Participatory strategy development for promoting renewable electricity generation

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4.1 Abstract

This paper presents a participatory process, in the course of which stakeholders identified an implementable strategy for promoting renewable electricity generation in a county in Germany. In the process, a new combination of participatory methods was applied, including two participatory modeling approaches that are based on causal networks and the participatory development of qualitative normative scenarios. After the participatory process the combination of methods was evaluated regarding the ability to 1) map out the diversity of stakeholders′ perspectives, 2) to grasp the complexity of the problem, 3) to make uncertainty of complex problems transparent and 4) to support the identification of implementable strategies. Evaluation results showed that the applied methods were able to fulfill criteria 1) to 3). Specifically, application of actor modeling lead to fulfillment of criteria 1) and 2), while normative scenario generation addressed criterion 3). Criterion 4) was only partly fulfilled due to lack of credibility of the Bayesian Network modeling results. This was caused by the high uncertainty of the conditional probabilities elicited from experts, as there is

little empirical system knowledge in particular about the potential effects of management options. On the other hand, stakeholders were not sufficiently involved in the construction and application of Bayesian Network models during the participatory process.

4.2 Introduction

To keep global mean temperature rise below 2 °C relative to pre-industrial levels, substantial cuts in anthropogenic greenhouse gas emissions through large-scale changes in energy systems are necessary, with global greenhouse gas emissions declining after 2020 to values that are 40-70% lower in 2050 than in 2010, and emissions levels near zero or below in 2100 [1]. This requires rapid improvements in energy efficiency and a tripling to nearly a quadrupling, by the year 2050, of the share of low-carbon energy supply from renewables, nuclear energy, fossil energy with carbon dioxide capture and storage (CCS), or bioenergy with CCS [1]. Low-carbon electricity generation is a key component of cost-effective mitigation strategies as decarbonization is expected to happen more rapidly in electricity generation than in the industry, buildings, and transport sectors. In global energy scenarios that lead to achieving the 2°C goal, low-carbon electricity supply increases from the current share of approximately 30% to more than 80% by 2050 [1]. Therefore, renewable electricity generation has become a very important approach to mitigation of climate change. The 2013 share of renewable energy sources in electricity generation within the European Union was 25%, significantly larger than the 12% share in gross inland energy consumption (including electricity, heat and transport) [105]. The European Union (EU) aims to increase share of renewable energy consumption of 12% to 20% and 27% in 2020 and 2030, respectively [106]. While there is no specific goal regarding renewable electricity production for the EU, Germany has the national goal to cover 35% of the electricity consumption from renewables by 2020, up from 25% in 2013 [107]. In Germany, the necessity to develop a electricity generation system that is based on renewable has gained a broad consensus at the national level [108]. However, stakeholders differ on what the best strategy is for transforming the electricity generation system. All stakeholder perspectives are equally legitimate and need to be taken into account in the development of national and region-specific transformation strategies. To this end, participatory processes need to be organized, in which relevant stakeholders are involved, learn about the complex and uncertain causal relationships within the system [109] and bring in their perspectives on possible transformation strategies. Strategies developed in such participatory processes are more likely to be relevant, legitimate and credible [110].

To achieve a successful participatory process, an effective design of the process including the choice of appropriate participatory methods is essential [15]. Participatory methods include focus groups, policy exercises, participatory planning, scenario analysis and participatory modeling [6, 10]. Participatory scenario development has been done in a wide range of cases including climate change management [10] and land management [111]. Bayesian Network modeling has been used as participatory modeling approach in an array of in environmental management problems including water management and conservation management (Chapter 3). Actor modeling that represents problem perceptions of individual acturs in a semi-quantiative manner has been applied, for example, in the problem field of pharmaceuticals in drinking water [112] or the problem field of microcontaminants in rivers [113]. Often, participatory scenario development and participatory modeling are combined in the way that qualitative scenarios are developed together with stakeholders and subsequently the scenarios are translated into a quantitative model by researchers [9, 114]. Strategy development in complex human-environment systems requires to (1) represent the system in a strongly simplified manner while grasping the complexity of the system [17] and (2) to consider uncertainty as a structural feature of complex problems in a transparent way [115]. Uncertainty can have many different types and sources [4]. Incomplete scientific knowledge of key environmental processes is one source of uncertainty, while other uncertainties are connected to people's behavior [116]. Mysiak et al. (2008) [117] point out that the uncertainty that needs to be addressed in participatory approaches goes beyond formal indices of uncertainty of data, methods or models. In participatory processes, uncertainty also relates to perceptions and feelings (e.g. "Do you believe in climate change?") and the elicitation of this type of uncertainty is challenging [118]. Another challenge is related to communication of uncertainty to stakeholders [119, 120].

This paper presents a participatory strategy development (PSD) process for promoting renewable electricity generation in a German county, in which a new combination of participatory methods was implemented and evaluated. A particular focus in the design of the PSD was to clearly identify and communicate the problem perspectives of the involved stakeholders and to improve and integrate system knowledge of the stakeholders, also by explicitly including uncertainty aspects. Relevant stakeholders from the private sector include the regional energy provider, bank finance group, power engineering. The policy/public sector was presented by municipalities, environmental agency, and the Energy Competence Center. While non-governmental organizations in the PSD were the farmers' association, nature conservation organization, and the chamber of industry and commerce and the chamber of handicrafts. The PSD and its outcomes are described in the next section. The description includes the setting of the case study, the four-step approach of the PSD and the applied participatory methods. The participatory methods include two participatory modeling approaches based on causal networks, actor modeling and Bayesian Network modeling, as well as the development of normative scenarios that was also supported by visualization in causal networks. Subsequently, the results of the evaluation of the participatory methods and of the outcomes of the PSD are presented. The methods are evaluated with regard to their abilities (1) to map out the diversity of stakeholder perspective, (2) to grasp complexity, (3) to take into account the uncertainty in the problem field and (4) to support the identification of mutually agreed, implementable and coherent strategies (policy outcomes). Finally, we provide recommendations on how to improve the application of the participatory methods. A detailed evaluation of social learning in the PSD is outside the scope of this paper and described in Düspohl et al. (submitted) [121].

4.3 Setting of case study

The county of Groß-Gerau is located close to Frankfurt in the state of Hesse in Germany. It covers an area of 453 km² and has about 252,000 inhabitants. The goal of the county is to cover 30% of the electricity consumption from renewable energy sources by 2020 and produce the renewable electricity within the county. The current generation of renewable electricity (data from 2007 [26]) is less than one percent of the electricity consumption (Table 4-1). In comparison, Germany has the national goal to cover 35% of the electricity consumption from renewables by 2020, while in 2007 14% were from renewable sources [107]. In Groß-Gerau, the potential for the generation of renewable electricity is about 20 times higher than the electricity consumption in 2007 (Table 1-1).

A PSD called "Renewable Electricity Generation in Groß-Gerau" (hereafter referred to as "REG Groß-Gerau) was set up to develop strategies to increase renewable electricity generation within the county and thus to reach the 30% goal. The composition of the group of altogether 13 stakeholders was decided together with the Energy Competence Center (EKC) of the administrative district of Groß-Gerau, the key stakeholder in the PSD. Throughout the PSD, the representatives of the newly established EKC played an important role as a multipliers, opinion makers and intermediaries between the research project and the implementation of its results [118]. The selected stakeholders covered a broad range of expertise representing private, scientific, policy and non-governmental sectors. The stakeholders were invited to participate in a series of workshops over the period of one year (between October 2011 and November 2012). The number of stakeholders that were represented varied among the workshops because new stakeholders were involved at a later stage or some stakeholders opted out after the first or second workshop.

4.4 Overview of the PSD: A four-step approach

The PSD “REG Groß-Gerau” consisted of four steps (Fig 4-1):

1) Describing the current system from a stakeholder’s perspective with actor modeling (AM). This included the generation of a combined perception graph that the stakeholders agreed on.
2) Exploring possible futures with qualitative normative scenarios
3) Quantifying the effects of actions on goal achievement using Bayesian Networks (BN)
4) Identifying implementable (short-term) actions based on BN results.

The participatory methods are described in section 4.3 below. The tasks, communication methods and products generated in each step of the PSD at certain times during the PSD are shown in Table 4-1. In total 14 interviews were conducted and four workshops were organized over the one-year period of the PSD. Step 1 was realized in workshops 1 and 2, while step 2 started in workshop 2 and ended in workshop 3. Step 3 and 4 were executed in workshop 4. Each workshop was conducted within half a day at the Energy Competence Center in Groß-Gerau.

Stakeholders were actively involved in most of the tasks throughout the PSD “Renewable Electricty Generation Groß-Gerau” (Table 4-1). In other tasks, they were consulted or requested to provide feedback. For example, stakeholders selected external influencing factors for renewable electricity generation, but they were not involved in the combination of external factors to develop two scenario frameworks (Task (11) in Table 4-1). Additionally, stakeholders were also not involved in the generation of BN structure (which, however, was influenced by the agreed upon combined sectoral perception graphs in step 1) and conditional probability tables (CPTs) (Task (15) and (16) in step 3, Table 4-1) as well as in running the BNs, due to time constraints. Stakeholders did not operate any software tools personally during the PSD.

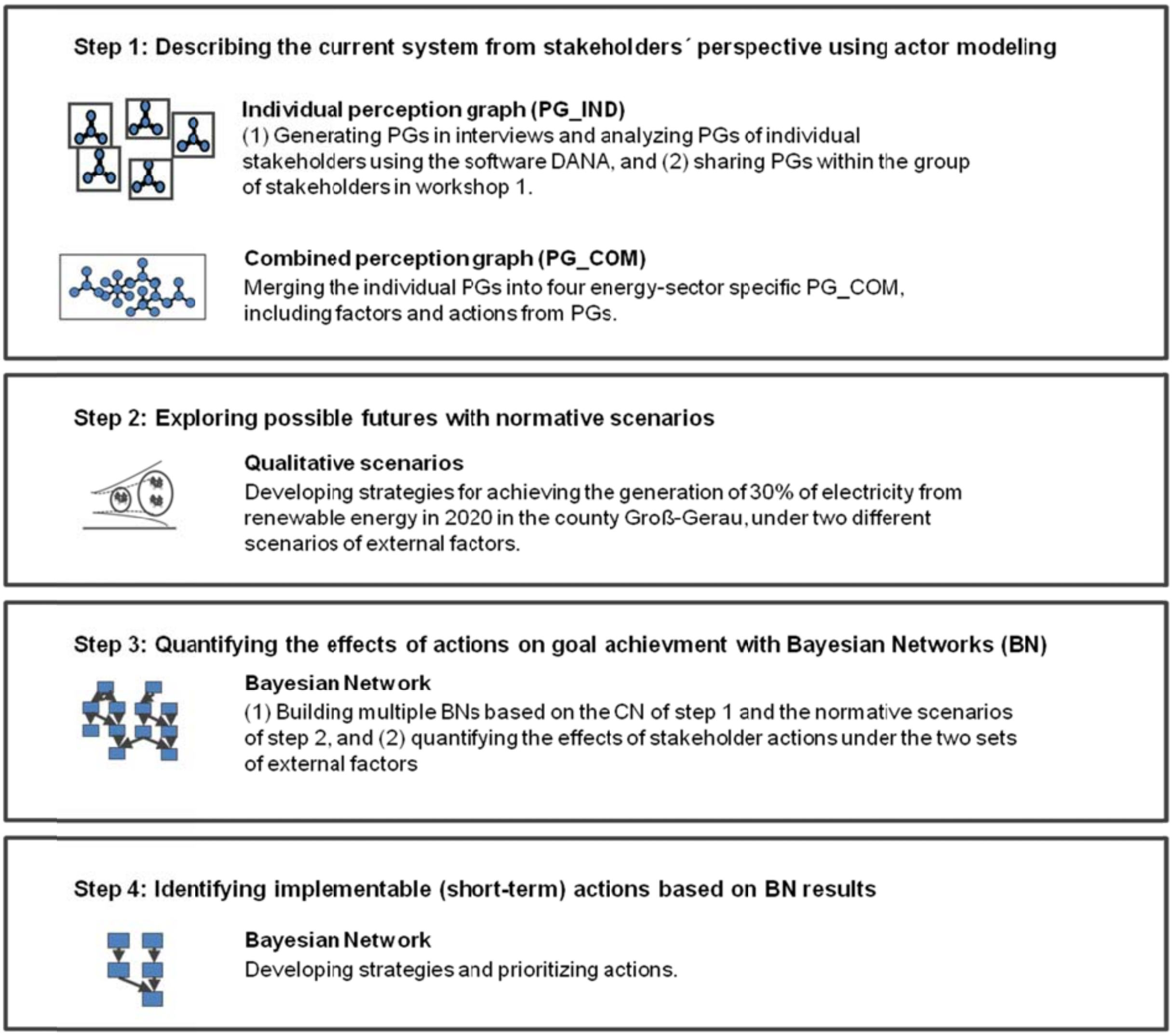

Figure 4-1: Steps of the participatory strategy development (PSD) with methods applied.

Table 4-1: Temporal sequence of the PSD "REG Groß-Gerau" with an overview of tasks, applied communication methods and products.

Steps	Date within process	Tasks (active persons)	Communication method	Products
0	Kick-off meeting (October 2011)	(1) To inform stakeholders about the strategy development and the current situation of renewable power supply in the county. (analyst) (2) To invite stakeholders to take part in the process. (EKC)	Leaflet with brief information about the participatory strategy development process was given to stakeholders	
1	Before workshop 1 (November 2011)	(3) To identify the perception of stakeholders and to generate individual perceptions graphs (PG_IND) including goals, factors and actions. (analyst) (4) To generate sector specific combined perception graphs (PG_COM). (analyst)	Individual interviews with relevant stakeholders (Appendices A and B)	14 PG_IND
	Workshop 1 (December 2011)	(5) To get to know the perception of other stakeholders involved in the process. (stakeholders) (6) To make stakeholders familiar with using causal networks. (analyst)	Introduction of each stakeholder using his/her PG_IND and exchange of PG_IND in a poster session	
		(7)To add actions to the different renewable energy sectors. (stakeholders) (8) To approximate a joint and integrative problem perception of all stakeholders as a basis for the development of an implementable strategy.(stakeholders)	Discussing different renewable electricity sectors (biogas, wind, solar and deep geothermal energy) in a World Café based on PG_COM developed by analyst. (Appendix C)	Four PG_COMs of different renewable energy sectors
	Workshop 2 (January 2012)	(9) To agree on the system as described by combined perception graphs. (stakeholders)	Showing combined perception graphs from task (7) and (8) on posters in a plenary meeting	
		(10) To identify external influencing factors for renewable electricity generation and their uncertainty. (stakeholders)	Normative scenario development I: Systematic collection of external factors that influence the production of renewable electricity using on cards (Appendix D)	

Table 4-1: Temporal sequence of the PSD "REG Groß-Gerau" with an overview of tasks, applied communication methods and products (continued).

Steps	Date within process	Tasks (active persons)	Communication method	Products
1	Between Workshop 2 and 3	(11) To combine external influencing factors into two different scenario frameworks (analyst)		Two normative scenario frameworks
		(12) To generate simplified PG_COM of renewable electricity generation without sectoral differentiation that include all external influencing factors identified in task (10) (analyst)		Simplified PG_COM without sectoral differentiation
2	Workshop 3 (February 2012)	(13) To identify with a perspective to 2020 internal actions for 30% goal achievement. (stakeholders) (14) To estimate final amount of renewable electricity generation under different scenario frameworks (stakeholders)	Normative scenario development II: Identification of two scenarios in groups based on simplified PG_COM and comparison of scenarios in a plenary meeting. (Appendix E)	
3	Between Workshop 3 and 4	(15) To generate energy sector-specific Bayesian Networks (BNs) based on PG_COM from step 1, scenarios of step 2 and input from experts. (analyst) (16) To quantify the effects of different actions for the power production out of renewable energies using the BNs. (analyst)	Interviews with experts of renewable electricity sector to modify BN structure and quantify conditional probability tables.	
4	Workshop 4 (November 2012)	(17) To show impact of actions on renewable electricity generation. (analyst and stakeholders) (18) To prioritize different (future) actions. (stakeholders)	Presentation and usage of three BNs (solar, wind and deep geothermal energy) in a policy exercise to support strategy identification. (Appendix F)	Comprehensive documentation on sector-specific PG_COM, two scenarios (storylines), three BNs (Appendix G)

Table 4-2 shows stakeholders who participated in the interviews and the four workshops. In the first workshop, stakeholders proposed to extend the stakeholder pool by including stakeholders from the finance sector, the chamber of handicrafts and the chamber of industry and commerce. Two additional representatives of stakeholders were interviewed after workshop 1. As the process evolved, stakeholder participation slightly decreased (Table 4-2). The last workshop had to be postponed once due to insufficient attendance. In some cases, more than one representatives of a stakeholder were present at the workshops.

Table 4-2: Participation of stakeholders' representatives in semi-structured interview (I) and workshops (WS) from different sectors.

Sector	**Stakeholders**	**I**	**WS 1**	**WS 2**	**WS 3**	**WS 4**
Private	Waste industry	x		x	x	
	Regional energy provider	x	x	x	x	x
	Utility company	x	x	x	x	
	Bank finance group	x		x	x	x
Scientific	Power engineering		x		x	
Policy/administration	Municipalities	x	x	x	x	
	Regional planning	x	x		x	
	Environmental agency	x	x			x
	Energy Competence Center	x	x	x	x	x
Non-governmental	Farmers' association	x	x			
	Nature conservation organization	x	x	x	x	x
	Chamber of Industry and Commerce			x		x
	Chamber of handicrafts	x		x		x
	Number of attending stakeholders	11	9	9	9	7

4.5 Participatory methods

In the PSD “Renewable Electricty Generation Groß-Gerau”, three main participatory methods were combined, semi-quantitative actor modeling (AM), participatory scenario generation and probabilistic Bayesian Network modeling (BN). Both AM and BN are based on causal networks that visualizes the system of interest. The perception graphs of AM represent the variety of problem perceptions of the individual stakeholders. These were used, in the first workshop, to introduce the stakeholder representatives, and were then amalgamated to a single causal network (analyst view). The two different quantification approaches for the qualitative causal networks allowed the sequential inclusion of the growing understanding of the system of interest. At the beginning of the PSD, the semi-quantitative AM described the system of interest in a more qualitative manner, while the probabilistic approach of BN included the more detailed knowledge of external experts. Bayesian networks were finally used for quantifying, in a probabilistic manner, the scenarios that developed the stakeholder representatives.

4.5.1 Actor modeling (AM)

AM is a conceptual modeling method that focuses on analyzing the specific problem perception of each stakeholder [112]. The perception of each stakeholder is elicited through an interview and depicted in a so-called perception graph (PG, Fig 4-2). A PG is a directed acyclic graph that depicts the causal relationships between the goals of the stakeholder, possible actions of the interviewed stakeholder and of other stakeholders, external drivers and relevant factors. The relationships are described in a semi-quantitative manner, on a scale of 7. The example PG in Figure 4-2 represents the problem perception of the stakeholder “environmental organization” on generation of renewable electricity in the county. A representative of the stakeholder represented the problem perception of his/her organization as a causal network (using post-its) in the form of linked goals, actions and factors, guided by the analyst during an interview. As can been seen in Figure 4-2, the two main goals of the environmental organization are to strongly increase renewable electricity generation while at the same time strongly decreasing land consumption for power production. Wildlife conservation should remain at the same level as today, and renewable electricity should help to increase regional income. Performing increasingly the action “consult costumers” would lead to increased achievement of the goal of increasing renewable electricity generation and increasing regional creation of value. A linking arrow labeled with a plus describes a positive correlation: a more intense execution of then the action (here put more effort into consulting consumers) leads to an increase in the (goal) factor (e.g. renewable energy production). A linking arrow labeled with a minus describes a negative correlation: a more intense execution of the action (or the increase of a factor) leads to a decrease in the (goal) factor. The software used for actor modeling is DANA (http://dana.actoranalysis.com/; Bots, 2007). Individual PGs of all interviewed stakeholder can be combined using the semi-automatic function in DANA to generate a combined PG that comprises the perspectives of all stakeholders and represents the joint system description (Fig 4- 3).

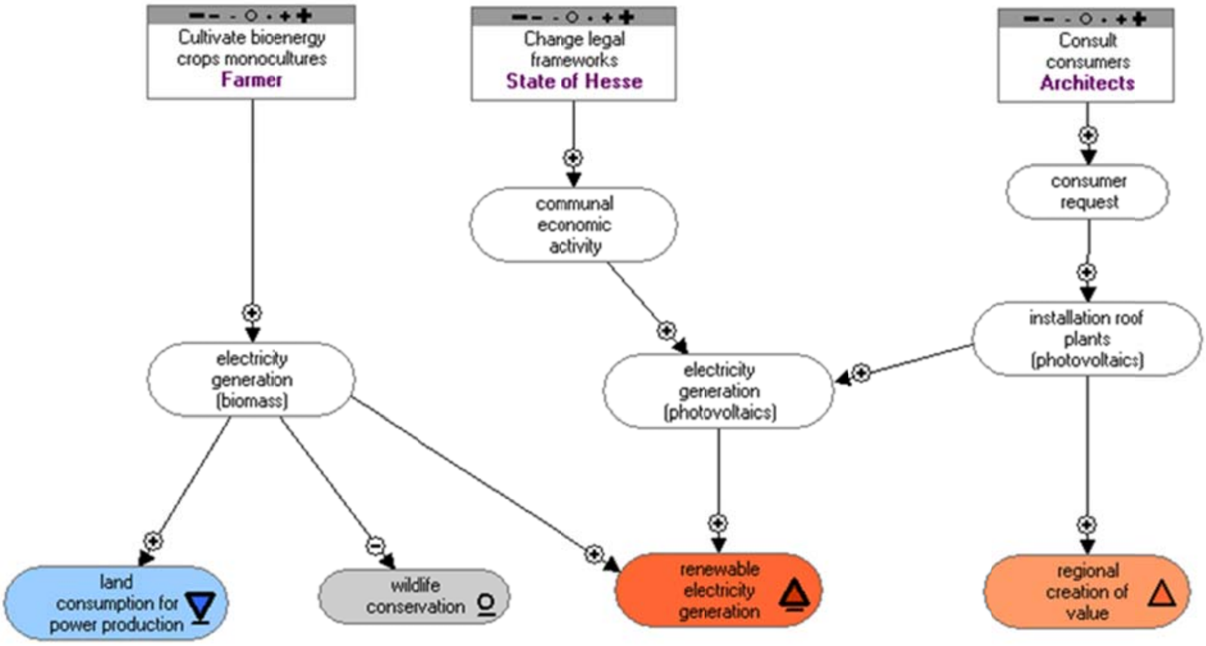

Figure 4-2: Perception graph (PG) of an environmental organization derived through an interview, depicting actions (rectangle), factors (oval, non -colored boxes) and goals (oval, colored boxes). For example the two main goals of the environmental organization are to increase renewable electricity generation (dark orange oval box) and at the same time to decrease land consumption for power production (blue oval box). Performing increasingly the action "cultivate bioenergy crops monocultures" would lead to increased achievement of the goal of increasing renewable electricity generation but lowered achievement of the goal of decreasing land consumption for power production.

4.5.2 Bayesian Networks (BNs)

Like the (combined) PG, Bayesian Networks (BNs), also known as Bayesian Belief Networks (BBNs), are causal networks that can integrate the problem perspectives of all relevant stakeholders. However, the causal relationships in a BN are described by conditional probabilities. Therefore, uncertainties associated with the causal relationships are explicitly represented in BNs [61]. Conditional probabilities can be derived from data or expert knowledge such that subsystems with diverse types and details of knowledge can be combined into one system. One of the advantages of using BNs is the short run-time of BN models which allows quick recalculations during a stakeholder workshop, thus allowing the participants to learn instantly from modeling results as a group [99]. We used the software Netica (http://www.norsys.com/netica.html) for BN modeling during the case study in Groß-Gerau.

4.5.3 Participatory development of normative scenario

As the county of Groß-Gerau had established a goal of 30% renewables, we selected a normative scenario development approach, also called backcasting [122]. In case of normative scenarios, stakeholders look backwards from a particular desired end-point or goal to the present in order to identify actions that lead to that goal achievement, under different scenario frameworks (i.e. different developments of external drivers). Scenario development supports stakeholders' recognition that multiple futures are possible and allows exploring how to achieve more desirable futures [123]. It encourages stakeholders to reveal their knowledge and problem perceptions about possible futures in a creative way. Additionally, exploring the future systematically enables the identification of constraints and dilemmas, leading to increased knowledge about the system among the stakeholders [21] and to awareness of the uncertainty of external factors that influences future developments within the county [124].

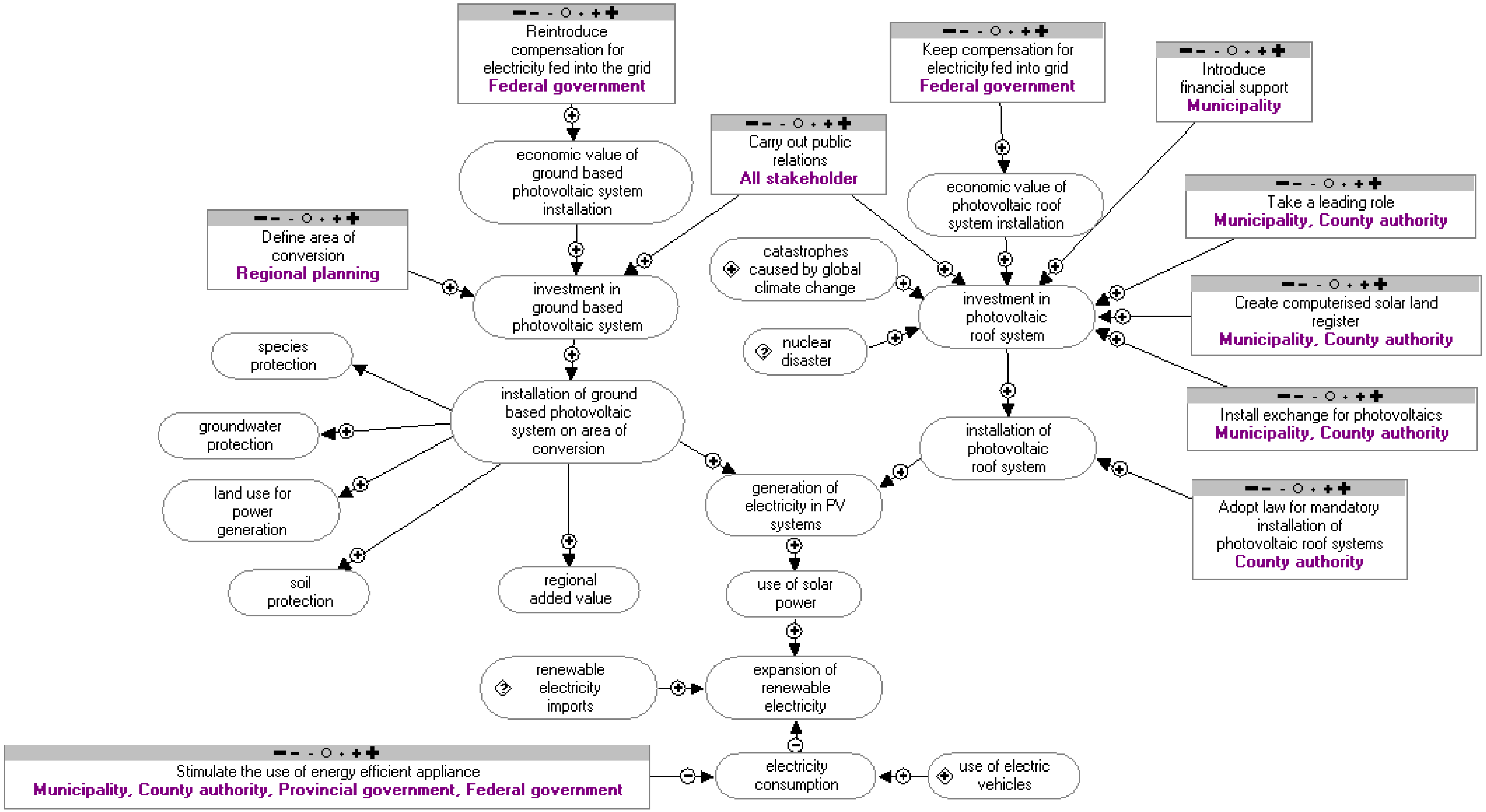

Figure 4-3: Combined PG for the photovoltaics (PV) sector developed in step 1 of the PSD including actions (boxes) and factors (oval boxes). The sector-specific combined PG describes the current system from stakeholders' perspectives by integrating relevant actions and factors stakeholders mentioned in their individual PGs. Individual goals of the stakeholders that were mentioned in the PGs are changed into factors (here: expansion of renewable electricity).

4.6 Steps of the PSD in detail

4.6.1 Step 1: Describing the current system from stakeholders' perspectives using AM

Step 1 started with a semi-structured interview with each stakeholder. The interviews took approximately 40 to 180 minutes. In each interview an individual perception graph (PG_IND) depicting the institutional perspective of the person interviewed (see example in Fig 4-1) was generated (Task (3) in Table 4-1). The PG_INDs were shared among the stakeholders in the first workshop (Task (5) in Table 4-1). The PG_IND were subsequently combined by the analyst to generate one combined perception graph (PG_COM) for each energy sector: photovoltaics, deep geothermal energy, biomass and wind energy (Task (4) in Table 4-1). The generation of a PG_COM was done semi-automatically using the software DANA. Semi-automatically means that the software DANA generated automatically a PG_COM by combining all actions, factors and goals specified by the stakeholders. Based on the results of factor occurrence analysis in DANA which indicates the perceived relevance of a factor, the analyst selected the most relevant actions, factors and goals of the stakeholders to be included in the PG_COM. In a PG_COM, goals mentioned by the stakeholders are presented as factors, while actions retained as actions and factors retained as factors.

The four energy sector-specific PG_COMs generated by the analyst, were discussed with the stakeholders in workshop 1 using a World Café format [125]. The PG_COMs were subsequently adapted based on the input given by workshop participants (Task (7) in Table 4-1). A World Café session provide the occasion for a larger group to communicate and exchange different perspectives [126]. In the described PSD, groups of four or five people commented on the PG_COMs assigned to each table (one table, one sector-specific PG_COM). In regular intervals (15-20 minutes), the participants randomly switched to other tables. The new group of people formed at the respective tables linked their ideas and insights to the previous discussion and captured them by writing and drawing on the table cloth. The discussion rounds ended after each group member had participated in the discussion at each table. A "table host" was responsible for moderating the discussion at the respective table. The host stayed at the same table throughout the entire World Café. Afterwards, table hosts presented the discussion results to the plenary. The output of the World Café was four concerted PG_COMs (see Fig 4-2 for the concerted PG_COM of the sector photovoltaic).

4.6.2 Step 2: Exploring possible futures with normative scenarios

In the second step of the PSD "Renewable Electricty Generation Groß-Gerau", qualitative normative scenarios were developed by workshop participants. Scenario development (Tasks (10) to (14) in Table 4-1) consisted of four steps: (a) Identify major external factors which influence strongly on reaching the 30%-goal (subsidy, etc.), (b) Combine external factors to scenario frameworks, (c) Generate a storyline that tells how the 30%-goal can be achieved by actions of the stakeholders in the county in the given combination of external factors and estimate final renewable electricity generation and (d) Compare different scenarios in the different scenario frameworks with stakeholders. Two normative scenarios with the goal to reach 30% renewable electricity generation in 2020 were developed from the future perspective of 2020. Nine external factors were identified by stakeholders that are assumed to have strong impacts on goal achievement (Table 4-3): Erneuerbare-Energien-Gesetz (EEG - Renewable Energy Act) feed-in tariff, level of lending rates, seismic events, nuclear disaster, total electricity blackout, development of storage technologies for electricity, efficiency, electricity consumption and domestic electricity prices in the county of Groß-Gerau. In the two scenarios each of the external factors was assumed to have developed in opposite directions. For example, the Renewable Energy Act that guarantees a certain price for the produced renewable electricity albeit at a decreasing rate over the years has been abolished in scenario 1 “Financial barriers & increase in electricity consumption”. In scenario 2 “Technological standstill & seismic events in Hesse”, it remains in force.

Table 4-3: Development of external factors in scenarios 1 and 2 written from the perspective of 2020.

External factor	Scenario framework 1 "Financial barriers & increase in electricity consumption"	Scenario framework 2 "Technological standstill & seismic events in Hesse"
EEG feed-in tariff	EEG feed-in tariff was stopped in 2014. Since then a quantity model regulates the subsidies for renewable energy electricity generation.	EEG feed-in tariff has decreased as planned since 2012.
Level of lending rates	Economic crisis has been surmounted and the level of lending rates is about 12%.	The level of lending rates has not increased since 2012. The level is about 2%.
Seismic events	No seismic event in Hesse and in Europe due to a drilling for deep geothermal plants.	Seismic events occurred in 2014 while drilling for deep geothermal power plant in Hesse.
Nuclear disaster	No nuclear disaster has happened since Fukushima 2011.	Another nuclear disaster has happened: An airplane crashed into a nuclear power plant in Sweden in February 2012.
Total electricity blackout	In 2015 a total electricity blackout occurred after a nuclear power plant was shut down. The blackout lasted one day.	No electricity blackout has happened.
Development of storage technologies	Rapid technical developments of electricity storage technologies. Domestic storage capacities and a comprehensive network of storage options ("power to gas") are available.	No profitable storage options have been available.
Advancing technical developments	Cost-efficient weak-wind turbines have been developed. In the photovoltaic sector efficiencies of 40% are obtained.	No cost-efficient weak-wind turbines have been developed. In the photovoltaic sector efficiencies of only 25% are obtained.
Electricity consumption	Due to technical developments (heat pumps, e-mobility) and lifestyle-related increase of electricity consumption (plus 10%).	Decrease of 20% of electricity consumption since 2012.
Domestic electricity prize	Electricity price for household has increased moderately since 2012 (plus 20%).	Low increase of electricity price for household since 2012 (plus 12%).

A simplified causal network (CN) of renewable electricity generation (without sectoral differentiation) was generated between workshop 2 and 3 (Task (12), Table 4-1). This CN included all nine external factors identified by stakeholders in Task (10) (Table 4-1). Based on this simplified CN, participants identified and discussed actions that could be taken in the two scenarios to reach 30% renewable electricity generation in Groß-Gerau. Figure 4-4 shows the actions selected for the scenarios: two actions in scenario 1 and eight actions in scenario 2. The goal of 30% renewable electricity generation could not be reached in scenario 1 mainly because the guaranteed feed-in tariff was stopped. Stakeholders felt that profitability of renewable electricity production would be too low to allow a sufficient expansion of renewable electricity production in Groß-Gerau.

Renewable electricity generation in each of the sectors in 2020 was estimated for each scenario by the stakeholders in a group discussion in two groups (Task (14), Table 4-1). Stakeholders estimated that in scenario 1, only 3% of total electricity consumption in Groß-Gerau will come from renewable sources and 30% in scenario 2 (Table 4-4). In scenario 2, about two third was assumed to come from photovoltaics, and none from deep geothermal energy (with the largest potential) due to the seismic events, Electricity consumption was assumed to remain constant at the 2007 value for both scenarios.

Table 4-4: Renewable electricity generation in 2020 in scenario 1 "Financial barriers & increase in electricity consumption" and scenario 2 "Technological standstill & seismic events in Hesse" as estimated by stakeholders in workshop 3.

Energy sector	**Power production in 2020, Mio. kWh_{el} / a (percentage of electricity consumption)**	
	Scenario 1	**Scenario 2**
Photovoltaics	?	220 (18.9%)
Deep geothermal energy	20–25 (1.6–1.8%)	0 (0%)
Biomass	16 (1.2%)	20 (1.7%)
Wind	0 (0%)	110 (9.4%)
Total electricity generation	36–41 (2.8–3%)	350 (30%)

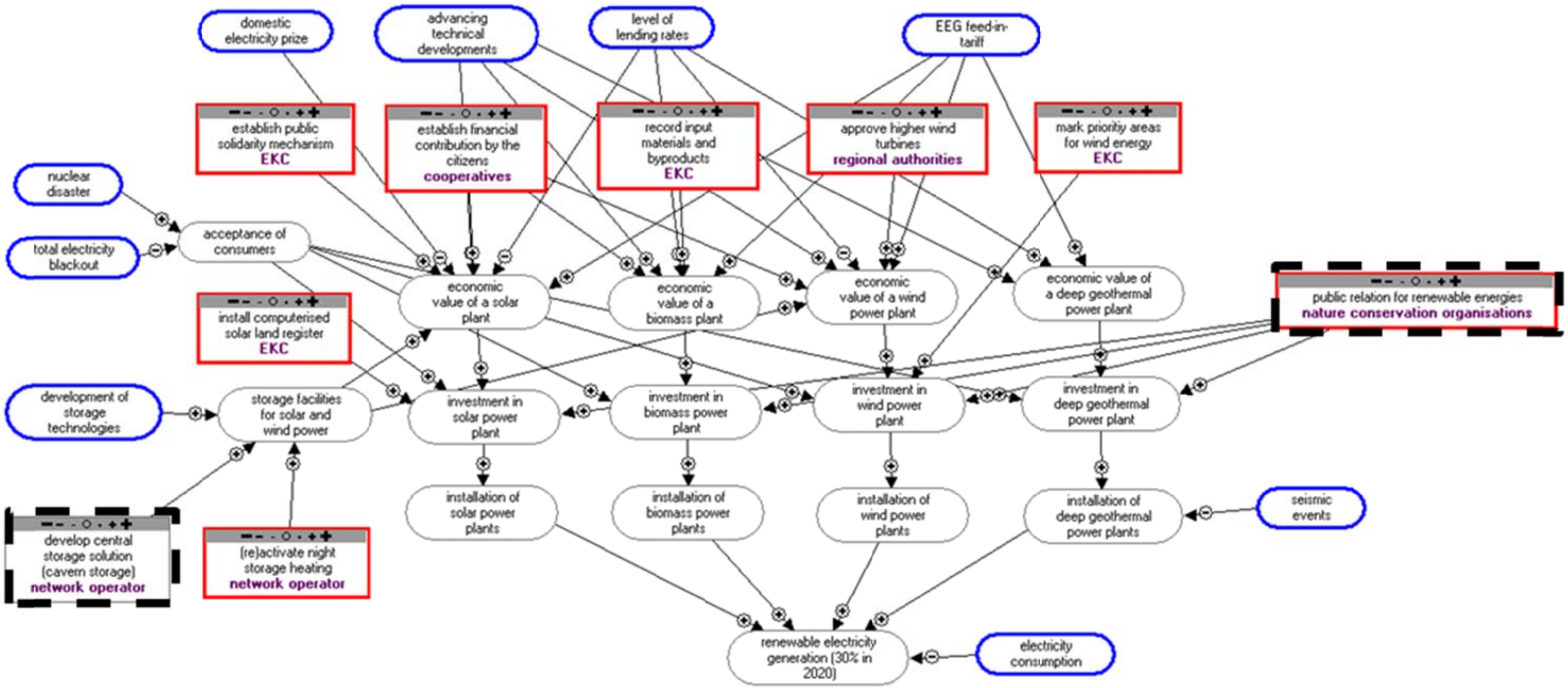

Figure 4-1: Scenario 1 “Financial barriers & increase in electricity consumption” and scenario 2 “Technological standstill & seismic events in Hesse” described in a simplified PG_COM combining the four energy sectors. Explanation: external factors (oval, blue framed), factors (oval, black framed), identified actions of scenario 1 (black dashed framed), identified actions of scenario 2 (red framed).

4.6.3 Step 3: Quantifying the effects of actions on goal achievement with BNs

The effects of actions on goal achievement for both scenarios developed in step 2 were quantified using Bayesian Networks (BNs). For this purpose, one BN was constructed for each energy sector (Task (14) in Table 4-1). The construction of a BN consisted of four steps: (a) construction of preliminary BN structure using the software Netica based on energy sector-specific CNs from step 1, (b) add external factors and identified actions from step 1 and step 2, (c) consultation of experts to modify BN structure and provide CPTs, (d) harmonization of stakeholder and expert input and development of the final structure and CPTs. For the BN construction, stakeholders from the participatory process and external experts (not involved in the PSD) were consulted [127]. Table 4-5 gives an overview of the consulted experts. The interviews took between one and two hours to get feedback on the BN structure and the CPTs.

Table 4-5: Consulted experts for the construction of BNs.

Information on	Internal experts	External experts
Photovoltaics	1	3
Deep geothermal energy	1	-
Biomass	1	4
Wind	0	2
Consumer behavior	-	1

The constructed BNs were used as input for discussion in Workshop 4. Figure 4-5 shows the BN of the photovoltaic (PV) sector PV. The main output variables in the BN of PV are the share of PV electricity production relative to total electricity consumption and the regional value added.

At the beginning of workshop 4, stakeholders received an introduction to BNs. The BN model was used interactively during the workshop to show stakeholders the effects of actions on renewable electricity generation in the sector PV, deep geothermal energy and wind. Due to time constraints, the BN for biomass was not presented at the workshop. Biomass is the energy sector with the smallest potential for renewable electricity generation in Groß-Gerau.

To quantify the effects of actions on the share of PV electricity generation, stakeholders were asked to complete the prepared form as shown in Table 4-6 (Task (17) in Table 4-1). Input nodes (relevant actions) were iteratively changed and the probability distribution for reaching the desirable future (output) was noted for the quantification of the two scenarios.

Table 4-6: Probability (%) for electricity generation from photovoltaics (PV) in percent of total electricity consumption in Groß-Gerau for two scenarios estimated by workshop participants, taking into account different actions identified in the PSD (a1 = public relation work, a2 = PV-system exchange, a3 = computerized solar land register, a4 = low-interest loans, a5 = obligation to build new PV-system).

	Share of PV electricity generation	**Probability (%)**						
		No actions	**a1**	**a2**	**a3**	**a4**	**a5**	**a2 and a3**
Scenario 1	0–6%	64.7	44.9	56.2	56.2	64.0	39.6	47.7
	6.1–12%	23.3	28.5	25.5	25.5	23.4	37.1	27.8
	12.1–18%	8.8	16.3	10.9	10.9	7.1	17.5	14.9
	18.1–24%	5.2	10.3	7.4	7.4	5.5	5.8	9.6
Scenario 2	0–6%	37.7	29.3	34.1	34.1	35	22.1	30.5
	6.1–12%	24.0	23.3	23.7	23.7	23.9	27.2	23.4
	12.1–18%	15.9	18.2	16.9	16.9	16.8	25.1	17.9
	18.1–24%	22.4	29.2	25.3	25.3	24.4	25.5	28.2

4.6.4 Step 4: Identifying implementable (short-term) actions based on BN results

In the last step of the PSD "Renewable Electricty Generation Groß-Gerau", stakeholders were asked to choose and discuss, based on the BN modeling results, (short-term) actions that need to be implemented to reach the desired goal in the county of Groß-Gerau regarding the generation of 30% electricity based on renewable sources in 2020. Workshop participants worked in groups of two and the chosen actions were put in a chronological order until 2020 (Task (18) in Table 4-1). The discussion results were presented and shared in the plenary session using the card technique. The cards were pinned on the board (one card, one action). The actions were then rated by participants by sticking adhesive dots on the cards. Cards with the most dots (points) were chosen to be the most relevant actions. Table 4-7 shows identified those actions that were rated with at least 4 points. None of the actions, except public relation work and obligation for PV systems were included in the BN.

Table 4-7: Actions to be carried out by each energy sector to support an accelerated implementation of renewable electricity generation in Groß-Gerau, identified and rated by stakeholders at Workshop 4.

Energy sector	Action	Responsible stakeholders	Points
All	Public relation work (energy fair)	All stakeholders	5
	Consult energy consultants	Energy suppliers	4
	Focus on integrated energy systems (power and heat)	Power company	9
	Encourage energy saving	County, municipalities and power company	7
PV	Obligation for PV systems	Municipalities	9
Wind	Define priority areas for wind energy	Not defined	6
Deep geothermal energy	Promote public support of deep geothermal energy	County, municipalities and power company	11

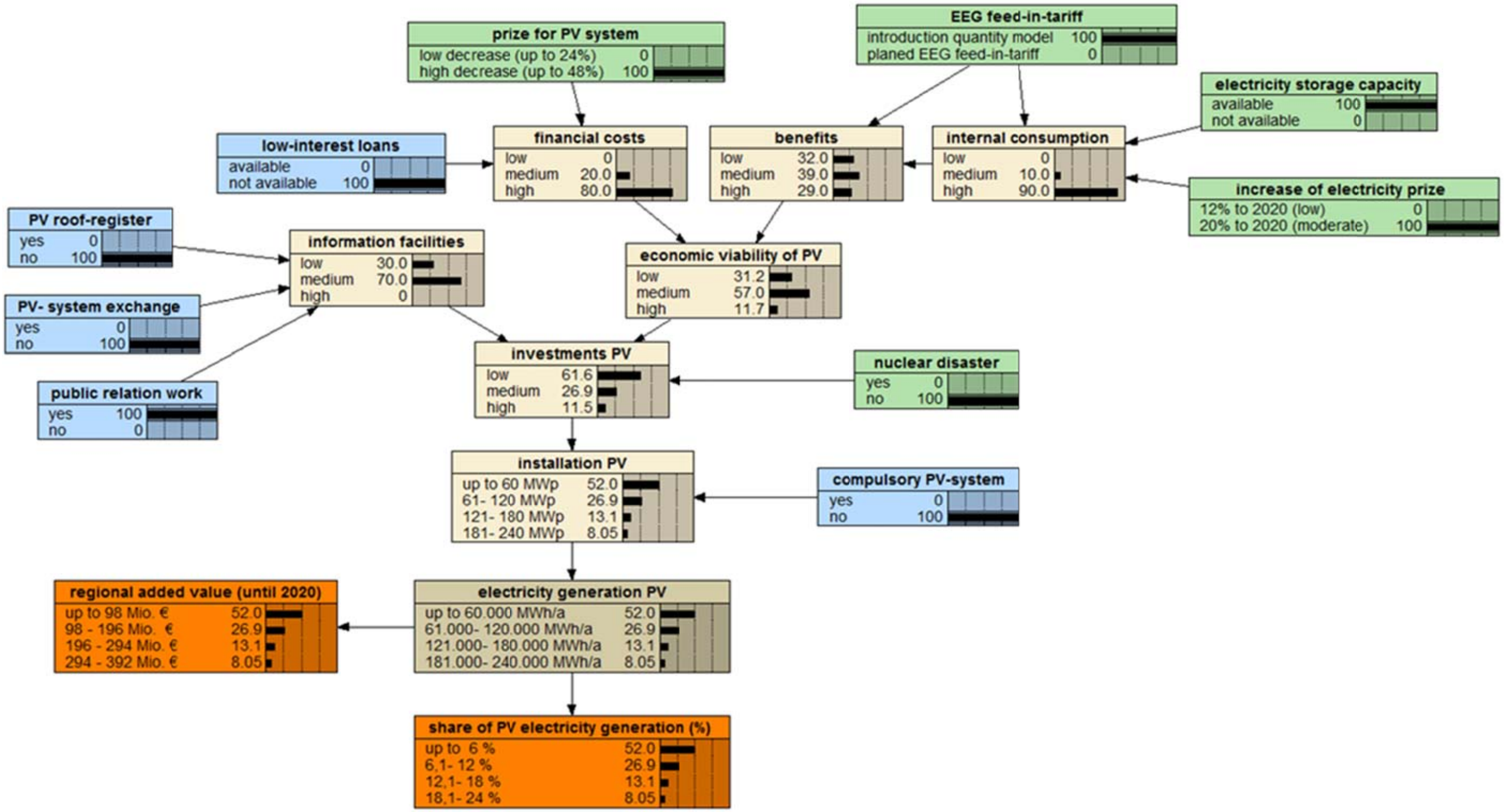

Figure 4-2: Bayesian network for the PV sector used in workshop 4 to quantify the impact of actions on the share of PV electricity generation and regional value (Green boxes: external factors, blue boxes: management interventions, brown boxes: factors, orange boxes: goals). In the boxes the probabilities of the different states of the factors are shown. For example, the probability that the electricity generated by PV is less or equal to 6% of the total electricity consumption in Groß-Gerau for scenario 1 is 52%.

4.7 Results: Evaluation of the participatory methods applied in the strategy development process

A Questionnaire was used to evaluate the combination of methods applied in the PSD "Renewable Electricty Generation Groß-Gerau" regarding their abilities (1) to map out the diversity of stakeholder perspective, (2) to grasp complexity, (3) to take into account the uncertainty in the problem field and (4) to support the identification of implementable and coherent strategies (policy outcomes). The questionnaire was distributed directly at the end of the last workshop. 10 stakeholder representatives participated in the survey (n = 10). Two of the stakeholders had participated only in the last two workshops. Therefore, not all questions were relevant for them. This resulted in n = 8 or n = 9 in some responses. Closed questions were posed in the questionnaire using a five-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, 5 = strongly agree). The following evaluation results describe the percentage of the different scores for each statement (Fig 6). The evaluation results are complemented by notes taken throughout the participatory process by the analysts. A detailed description of evaluation results regarding social learning can be found in Düspohl et al. (submitted) [121].

4.7.1 Map out diversity of stakeholders' perspectives

Questionnaire respondents were asked to rate the statements regarding the ability of the individual methods to map out the diversity of stakeholders´ perspectives. With 7 out of 8 respondents agreeing, individual perception graphs PG_IND were judged to be more suitable for making the perspectives of other stakeholders transparent to the individual stakeholders than combined perception graphs PG_COM or scenario development (Fig 4-6). However, only 3 out of 8 stakeholders felt that the PG_IND made the own stakeholders´ perspective transparent to the others stakeholders, a lower rating than for PG_COM (Fig 4-6).

4.7.2 Grasp complexity

PG_COMs and BNs were evaluated in the questionnaire regarding their ability to highlight important interconnections of the system to support the development of system knowledge. Stakeholders rated PG_COMs developed in the first step of the PSD higher than BNs (6 out of 8 stakeholders agreed/strongly agreed for PG_COMs, while only 3 out of 10 stakeholders agreed/strongly agreed on BNs, Fig 4-6).

4.7.3 Take into account uncertainty

The development of normative scenarios and the quantification of the developed scenarios with BNs aimed at the transparent presentation of uncertainty in the problem field. 6 out of 10 stakeholders agreed/strongly agreed that normative scenarios are well suited to represent the influence of external factors and their uncertain development (Fig 4-6).

4.7.4 Policy outcomes

The last step of the PSD aimed at identifying implementable actions for renewable electricity generation in Groß-Gerau based on BNs. During this last step of the PSD, we were able to observe that stakeholders did not refer to the results of the BN-modeling session to choose actions to develop a strategy. The evaluation results show that only 4 out of 10 stakeholders found that BNs support the selection of actions (Fig 4-6). Even less stakeholders (3 out of 10) agreed that BNs showed possible actions of stakeholders.

The developed strategies were evaluated against three statements using the questionnaire (Fig 4-6). Most of the respondents agreed that the developed strategies reflect their understanding, while the majority neither agree nor disagree if the developed strategies are concrete and realizable. Only 4 out of 9 respondents agreed that the developed strategies are coherent.

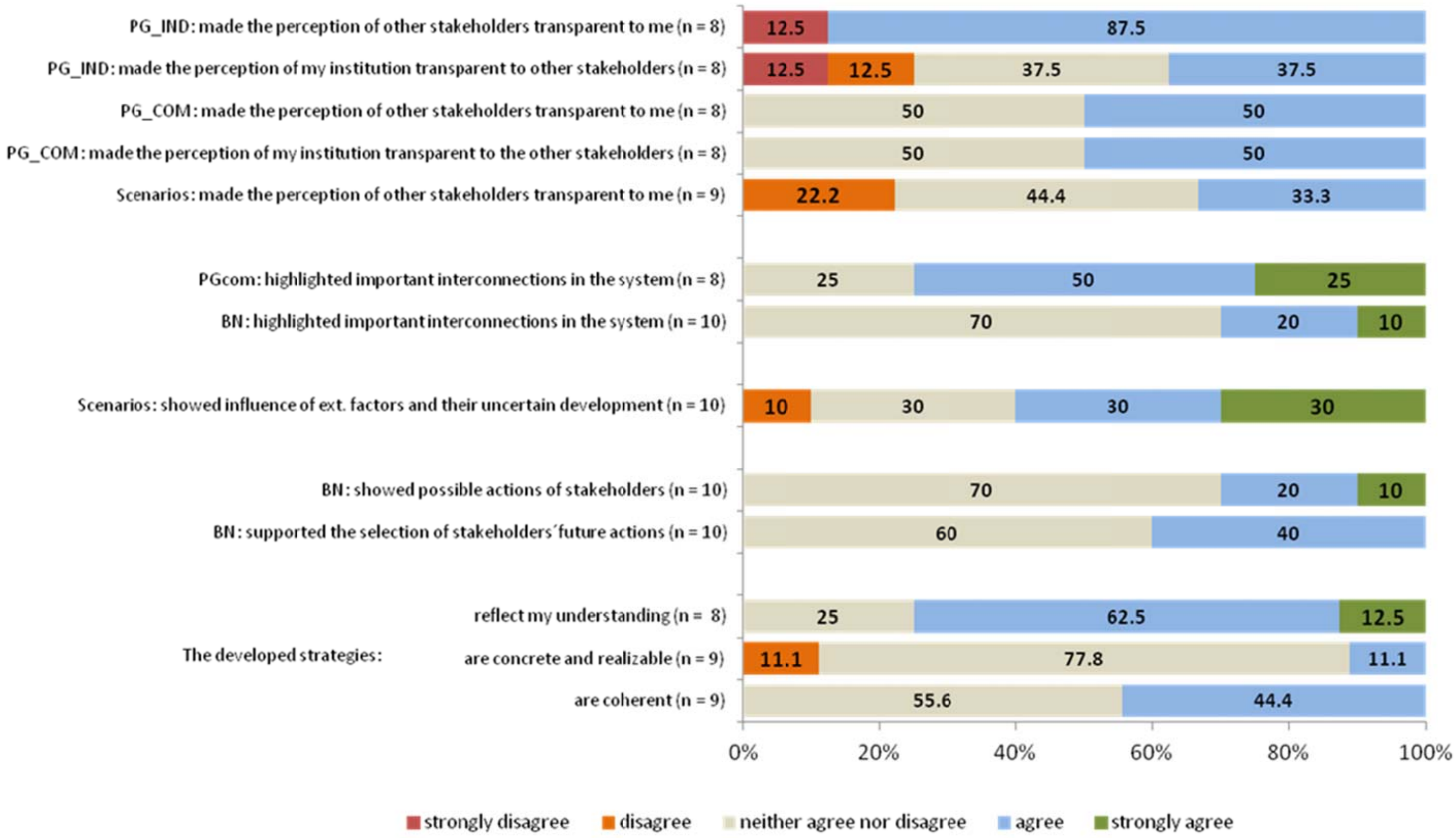

Figure 4-3: Evaluation of the applied participatory methods and the policy outcomes of the PSD.

4.8 Discussion

We now discuss the evaluation of the suitability of the applied participatory methods for achieving the four specific goals 1) to map out the diversity of stakeholders´ perspectives, 2) to grasp the complexity of the problem, 3) to make uncertainty of complex problems transparent and 4) to support the identification of implementable strategies of the PSD "Renewable Electricty Generation Groß-Gerau". When analyzing evaluation results of a questionnaire it is important to point out that some results from the questionnaire might be biased, as stakeholders might give more socially wanted answers, or might want to give themselves the impression that their time was well spent in the participatory process [128].

4.8.1 Map out diversity of stakeholders´ perspectives

Evaluation results showed that the PG_IND was evaluated to be better than the PG_COM and scenarios to make the perspectives transparent of each stakeholder to the other stakeholders. However, the PG_IND was evaluated less useful to make the own perception transparent to the other stakeholders. A possible explanation for this evaluation result might be: Stakeholder had the feeling that their own perception is far too complex than it could be explained within a PG_IND. In addition, stakeholder presenting their perception with a PG_IND received no feedback in the workshops from the analysts or other stakeholders that their perception was understood.

From a researcher point of view, the visualization of stakeholders´ perspectives in a causal network like PG_IND is a simple, but efficient method to map out the diversity of stakeholders´ perspectives in a PSD. Using an image instead of words is a method to describe the perspective of each stakeholder systematically and to allow abstract thinking of the stakeholder that generates the causal network and the observer of the image. The evaluation results can be explained by taking into account that stakeholder had the possibility to use the PG_IND to introduce themselves in front of the other stakeholders. In comparison PG_COM was combined by the analyst and discussed with stakeholders in groups during the World Café without focusing on the perspective of individual stakeholders.

Causal networks used in this PSD include goals of the stakeholders, possible actions of stakeholders, external drivers and relevant factors of the system. A critical aspect that needs to be taken into account is the questions which aspects cannot be displayed in the causal network but might be relevant to describe the complete perspective of a stakeholder. It is not possible to display power relations in the causal network, meaning which of the identified stakeholder is more powerful than the other stakeholders. In real world power relations are important to be considered in the stakeholder perspective to understand why and which actions are implemented [129].

4.8.2 Grasp complexity

The PG_COM was judged to be more suitable to highlight the important interconnections of the system than BNs. This might be explained by the different degree of participation in the construction of the PG_COMs and BNs. Most stakeholders were not involved in the construction of the BN model, except those that served as experts in step 4 (Table 4-1) but only saw the final networks and the computational results. Many studies point out that the stakeholders should take the same steps as the modeler to increase the credibility of modeling outcomes [130, 131]. In contrast, the structure and content of the BNs were partly changed during the interviews with external experts and by the analysts. The construction of the PG_COM involved a higher degree of stakeholder participation. Stakeholders had the possibility to intensively discuss the structure and content of the PG_COMs in the World Café.

Participating researcher felt at the end of the PSD those BNs could have been even more useful to grasp complexity than PG_COM. More quantitative information is provided in the conditional probability tables in a BN than in a PG_COM. A more detailed introduction of the BNs for the stakeholders might have generated better evaluation results from a stakeholder perspective regarding the ability of BNs to grasp complexity. However, both causal network, PG_COM and BN, are acyclic; they do not support feed- back loops [56]. Being able to model feedback loops is sometimes beneficial to describe the complexity of a system. Additionally it is difficult to model spatial or for this case study more relevant temporal dynamic in PG_COM or BNs. There is the possibility to model temporal or spatial dynamics by using a separate BN for each time slice, however, this often represents a significant effort for the modelers and finally for stakeholders.

4.8.3 Take into account uncertainty

Normative scenario development was perceived by 60% of the stakeholders to be able to present the uncertainty of external factors and their development. In line with the findings of Berkhout et al. (2002) [21], participatory scenario development can better support the exploration of key uncertainties for the regional development than regular system analysis, although participatory scenario development process requires more time and effort. Comparing the selection of external factors included in the scenario development to selection of external factors during the scenario development by Enfors et al. (2008) [123] stakeholder ranked the key external factors by uncertainty and importance. In the PSD "Renewable Electricty Generation Groß-Gerau" stakeholder were not explicity asked about the uncertainty of external factors but only about their importance.

We did not ask the stakeholders to evaluate the BNs regarding their ability to represent and account for uncertainty as stakeholders were only shortly exposed to BNs and their results. Similar to the previous point (4.2) researcher assumes that a more interactive and transparent construction and application of the BNs would have led to a good evaluation of BNs regarding their ability to take into account uncertainty, if the BNs would have been evaluated.

4.8.4 Policy outcomes: developed strategies

The bad evaluation results for BNs regarding their capability to show possible actions and to support the selection of possible actions of stakeholders are underpinned by researchers´ observation that stakeholders did not refer to the BN modeling results when selecting the possible actions for a strategy to reach the 30% goal of the county. The explanation for the evaluation results and the observation goes in hand with the explanation for the requirement to grasp complexity (section 4.2) and take into account uncertainty (4.3): stakeholders were not involved in all steps to construct and apply BNs. Stakeholders might have felt that external experts and the analyst influenced the choice of actions that were integrated in the BNs. This result can be connected to thoughts of van de Kerkhof and Wieczorek (2005) [132] who pointed out that a PSD could be jeopardized by opinions and interests of the dominant stakeholders whose share of conversation might be higher during the workshops.

The policy outcome in the problem field was not supported by the BN modeling results. From a researchers perspective the evaluation results might be in addition be explained by the feeling of the stakeholders that the conditional probabilities filled in by the external experts are highly uncertain themselves. Knowledge of experts about the effect of the actions included in the BN on implementation of renewable energy generation is just too poor due to the lack of empirical studies or experiences. Also, the very generic formulation of the actions makes it difficult to quantify causal relations, i.e. do public relations

However, stakeholders thought that the identified strategies reflect their understanding and are coherent, but not concrete and realizable. One explanation of this evaluation result might be the generic nature of the formulation of actions like "do public relation work" or "encourage energy saving". At the end of the last workshop, stakeholders also asked for further meetings to concretize the identified actions.

The real-world problem of our PSD was framed by the 30%-goal of the county Groß-Gerau. This direct link to a formal political decision-making process may be both an advantage and a disadvantage [132]. In our case the binding nature of the PSD with the 30%-goal helped to focus during the entire process on identifying implementable and mutual agreed strategies.

4.8.5 Further aspects

A related point that deserves attention and needs to be handled with care is the sometimes ambiguous distinction between research and problem solving goals, i.e. the PSD as an instrument of analysis and research, and the PSD as an instrument of identifying implementable strategies [133]. The two goals are mutually dependent but the double nature of the process and of the role of the stakeholders may be a source of tension. One of the stakeholder representatives mentioned after the last workshop that the research team was focusing on the application of participatory methods instead of the identification of implementable strategies. He had the feeling he was taking part in a research experiment.

Another explanation for the evaluation of the developed strategies to be less concrete and realizable that goes beyond the application of participatory methods is the fulfillment of the role as key stakeholder of the EKC [132]. During the PDSP, the EKC did not promote the PSD to the public. The EKC was represented by less empowered and committed staff during the workshops which might have created the impression that the PSD was not relevant for the EKC, and the EKC was not interested in implementable policy outcomes. Comparable results are described in the study of Fenton et al. (2014) [134].

4.9 Conclusions

We set up a participatory process to support the development of implementable strategies for the renewable electricity generation in a county in Germany, Groß-Gerau. The PSD consists of four steps that are supported by selected participatory methods: (1) describing the current system from a stakeholder's perspective with actor modeling, (2) exploring possible futures with normative scenarios, (3) quantifying the effects of actions on goal achievement with Bayesian Networks (BN) and (4) identifying implementable actions based on BN. The PSD and applied participatory methods were evaluated using a questionnaire, complemented by observation and documentation. We wanted to find out if the combination of methods is successful with respect to their abilities (1) to map out the diversity of stakeholder perspective, (2) to grasp complexity, (3) to take into account the uncertainty in the problem field and (4) to support the identification of mutually agreed implementable and coherent strategies (policy outcomes). The evaluation results showed that the applied combination of methods was able to achieve the first three objectives, even if the modeling methods are missing some technical aspects like modeling dynamics or feedbacks. The fourth objective was only partly achieved in the PSD.

4.9.1 Lessons learned

Based on the experience gained in the PSD we suggest the following modifications to the PSD.

- To clarify goals and responsibilities a coordinative plan among the researchers and key stakeholder should be drafted at the beginning of the PSD [135]. This would include the responsibility for public relations of the PSD in the media [136].
- To give stakeholder the feeling that their problem perception was clearly understood by the other stakeholders, we recommend a short feedback session after the presentation of each PG_IND.
- To increase the awareness of the uncertainty of future development of external factors, we suggest asking stakeholders to explicitly rank the external factors during the step of scenario development with regard to their importance and their uncertainty.
- To overcome the problem that stakeholders did not refer to the BN modeling results when selecting the possible actions for a strategy to reach the 30% goal of the county, we recommend a different construction and application procedure with more time for stakeholders to work on BNs. In a first step experts would be asked to develop the conditional probabilities together with the analyst before a workshop. Afterwards the experts explain exemplarily their beliefs about conditional probabilities to the stakeholders during a workshop. This procedure increases the transparency and credibility of the BN modeling results and as a consequence increases the buy-in of modeling results. However, there are still open questions regarding the applicability of BNs in such a new problem field. Empirical system knowledge including the knowledge about the effect of certain action to promote renewable electricity generation is lacking. Future research should define the degree of system knowledge

that is needed to make useful quantitative statements and possibly to support the choice of appropriate strategies by using conditional probabilities.

– An additional workshop focusing on concretizing the identified actions should be organized at the end of the PSD. In this workshop, best practice examples from other regions should also be presented to create preconditions for the successful implementation of the identified actions.

The modification of the PSD “Renewable Electricty Generation Groß-Gerau”would allow setting up a PSD which supports the identification of implementable and coherent strategies as policy outcome (goal 4). We conclude that the advantages of the application of the combination of participatory methods in a PSD justify the effort for stakeholders and researchers participating in a PSD. Next to the evaluated achieved goals of the application of the combination of participatory methods, the combination helps to structure the PSD and to increase discussion among stakeholders in comparison to standard methods like group discussions. Finally we want to refer again to Düspohl et al. (submitted) [121]. This paper describes social learning among the stakeholders as triggered (at least partially) by the PSD as additional benefit of the entire PSD process. The effect of the PSD process on stakeholders and their relations among each other might be as important as the policy outcomes of the PSD. Well-designed participatory modeling within a well-structured participatory process has the potential to improve detailed scientific modeling by providing stakeholder knowledge otherwise not available to the modeler. On the other hand, it may improve stakeholder dialogues that would otherwise be confined to discussions, i.e. verbal exchanges of perspectives.

4.9.2 Future research steps

To get a deeper understanding about the applicability of the combination of participatory methods it would be interesting to apply the methods in a problem field with a higher degree of system knowledge at least for a part of a problem field provided by measurements, surveys or detailed modeling. A promising problem field may be local-scale land use that may be guided by optimization of ecosystem services. Furthermore, a problem field with more conflictual perspectives than in our case studyfield would allow analysing the ability of the participatory methods to reduce tension among stakeholders and achieve compromise.

5

Evaluating social learning in participatory strategy development processes – Lessons learned from a case study for renewable electricity generation

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Abstract

It is widely recognized that participatory processes are essential for social learning. However, there is confusion about what social learning is and how social learning can be measured. Relying on a selected definition of social learning, this paper presents an evaluation approach to detect the occurrence of social learning in participatory strategy development (PSD) processes. The context in which the PSD-process takes place in this study is that of a German county's effort to promote and implement the generation of renewable energy. Relevant stakeholders representing various organizations, including the county authority, plant operators, financial institutions, and NGOs participated. At the end and two years after the process com-

menced, the social-cognitive and social-relational dimensions of social learning of the participated stakeholders were evaluated using a combination of qualitative and quantitative methods. These methods included an innovative before/after comparison of the perceptions of stakeholders based on perception graphs (before/after PG), a questionnaire, and telephone interviews. Our research showed that the applied methods were suitable for evaluating the selected components of social learning on the social-cognitive dimension comprised by: (a) awareness of each other's sometimes different goals and perspectives; (b) shared problem perspective; (c) understanding of the actors' interdependence; (d) understanding of the complexity of the management system; and on the social-relational dimension with (e) learning to work together; (f) trust; and (g) the creation of informal as well as formal relationships. Particularly, we found out that the before/after PG is a useful method to detect (b) and (d), while (a) and (c) only partly were detected. A well-designed questionnaire enables researcher to evaluate all selected components of social learning. Complemented with methods we gained from literature, we give an overview of evaluation methods for the evaluation of social learning as an emergent property of a participatory process and suggest generative evaluative questions in a questionnaire. We conclude that evaluation methods need to be included in future research that focus not only on the stakeholder engagement but also on the triggered societal effects.

5.1 Introduction

Participatory processes have been widely employed in environmental management. They facilitate productive discussions where participating stakeholders share their knowledge and perspectives of the issues at stake, receive new information from experts, deliberate on possible decision options, and jointly develop interventions and change strategies. It is generally assumed that such interactive processes both require and enable social learning among participating stakeholders [23, 54, 133] which in turn encourages and enhances collaborations and joint actions [137]. It remains, however, an open question how the effect of a participatory process on social learning can be evaluated.

Despite the avalanche of papers on social learning in the context of environmental and resource management [138] there are hardly any studies trying to evaluate social learning. Numerous studies that claimed social learning had occurred as a result of participatory processes simply described the elements of stakeholder participation but only rarely any formal evaluation of supposed social learning [54, 139]. Often, conclusions about social learning were derived based on the ex ante evaluation of the design and process of participation. Criteria for evaluating participation in those cases include the inclusiveness of stakeholder involvement [140], acceptance criteria

[141], as well as fairness and competence [142]. It is assumed that these criteria are preconditions for social learning. A positive score on these preconditions for social learning makes social learning more likely to occur.

The actual and direct assessment of social learning is challenging. Firstly, there is a lack of a clear definition of social learning. Secondly, there is a lack of consistently defined components of social learning that can be evaluated [143]. Thirdly, it is difficult to rate social learning or its components [24]. To evaluate social learning, a clear understanding of the concept of social learning as well as the mechanisms through which it occurs is first and foremost required. Then, criteria and appropriate methods for evaluating social learning are needed to assess if the goals of learning interventions have been met.

In this paper, we present the evaluation of social learning in a participatory strategy development (PSD) process that aimed at increasing the generation of renewable electricity in a county in Germany. The applied evaluation methods were: 1) determination of changes in the problem perception of the participants using perception graphs generated before and after the PSD (before/after PG), 2) a questionnaire distributed at the last workshop of the PSD and 3) semi-structured telephone interviews conducted two years after the PSD.

We explored the following research questions:

1) Did the applied combination of evaluation methods lead to reliable evaluation of the selected components of social learning?
2) What are the advantages and disadvantages of applying the before/after PSD?
3) What aspects of social learning could not be evaluated due to the choice of social learning components?

In the next section, we provide the definition of social learning that we use in this paper and present the components of social learning as well as state of the art of its evaluation. This is followed by a short overview of the design and implementation of the participatory strategy development process on accelerating renewable electricity generation in the county Groß-Gerau in Hesse, Germany. Subsequently, we describe in detail the evaluation methods we applied to evaluate social learning and the results we obtained. We then answer the research questions in the result section. The paper ends with lessons learned and recommendations for improving the evaluation of social learning.

5.2 Social learning and its evaluation

5.2.1 Definition of social learning

What is social learning? The literature is often vague when it comes to defining the concept of social learning. Early work in psychology defined social learning as learning through the interaction with others [144]. This definition is not very useful, because any learning takes place in interaction with others. According to Pahl-Wostl and Hare (2004) [133], social learning is a process of learning and negotiation within a management process where higher priority is given to communication, sharing perspectives, and development of adaptive strategies for solving problems than to searching for optimal solutions. Furthermore, they added that social learning is "an iterative and ongoing process that comprises several loops and enhances the flexibility of the social-ecological system and its ability respond to change [133]. Reed, Evely, Cundill, Fazey, Glass et al. (2010) [53] describe social learning as an implicit "process of social change in which people learn from each other in ways that can benefit wider social-ecological systems". According to Muro & Jeffrey (2008) [139], learning requires active social participation in the practices of a community and emphasizes the dynamic interaction between people and the environment in the construction of meaning and identity.

Some studies confuse the concept of social learning with the conditions or methods necessary to facilitate social learning such as stakeholder participation. As defined by Fernandez-Gimenez, Ballard, & Sturtevant (2008) [145], social learning is "an intentional process of collective self-reflection through interaction and dialogue among diverse stakeholders". Participatory processes may stimulate and facilitate social learning, but it cannot be assumed that participation inevitably leads to social learning. Besides, social learning can take place without any planned participatory process [53]; for example, it can occur peer-to-peer via social networks, supported by the use of mass media or other non-participatory means.

Frequently there is also confusion between the concept itself and its potential outcomes. Social learning is considered to be both a process of people learning from each other as well as an outcome. The learning that occurs as an outcome of social interactions is often defined in relation to the wide range of additional outcomes of the participatory process.

There is still little consensus and lack of clarity about the conceptual basis of social learning [146]. The confusion about concepts of social learning reduces the applicability of the concept. Again, without any clarity about the definition of social learning, it becomes very difficult to facilitate social learning in social-ecological systems. Social learning should include social-cognitive and social-relational dimensions [143].

In this article, we consider social learning as an outcome of a participatory process and define social learning as a series of semi-facilitated and semi-structured interactions between a heterogeneous group of stakeholders resulting in a change in social cognition of the participants and the relationships they have with one another.

5.2.2 Components of social learning

In this case study, we evaluate social learning based on the components introduced by Pahl-Wostl & Hare (2004) [133], which we cluster according to pertain to the social-cognitive and social-relational dimensions which correspond well with the outcomes distinguished in the proposed definition (Table 5-1). For the first dimension, the components for social learning are the awareness and convergence of stakeholders' perspectives on the problem and its possible solutions and risks as well as on their own and the other stakeholders' positions and responsibility with regard to solving the problem [23, 133]. Components for the change in the social-relational dimension are the development of trust, improved communication and better working relations [5, 147], and changes in stakeholders' networks [137].

5.2.3 Evaluation of social learning

Evaluation in general is an examination and judgment of the accomplishment and effectiveness of certain efforts [148].It requires appropriate methods that are be replicable [149]. A replicable method includes a detailed description for carrying out a sequence of actions rather than a vague guideline. Methods with a quantitative character in general have a higher replicability than qualitative methods as they mostly involve prescriptions for carrying out specific procedures and allow statistical analysis. Qualitative methods however permit the evaluator to study selected issues in depth and detail, for example the way respondents phrase particular ideas. Therefore, a mixed-method approach using both qualitative and quantitative methods is preferred. Methods which have been used for the evaluation of social learning include semi-structured interviews, focus groups, questionnaires, and observations (e.g. [150]). The combination of methods that we use in our case study to evaluate social learning is described in more detail in Section 4.

5.3 Description of the case study of a participatory strategy development process

We designed and implemented a PSD process to increase renewable electricity generation in a county in Germany, to reach 30% coverage of electricity consumption from renewable energy sources by the year 2020 [151].The transformation of the electricity generation system can be considered to be an unstructured and uncertain policy issue. Many different interests are involved, including mitigation of climate change, security of energy supply, sustainability, and independence from energy supply from politically unstable regions. The uncertainty of the issue is due to a number of aspects, including public acceptance, financial feasibility, affordability, technological developments, or the existence of national programs for the promotion and implementation of renewable energies.

Relevant stakeholders need to be engaged in the strategy development process to represent diverse interests in and perceptions on the transformation of the electricity supply system. In the preparation phase of our participatory process, fourteen stakeholders were selected. Stakeholders included plant and grid operators, farmers, nature conservation associations, banks, environmental agencies, municipalities, public utilities, and the county authority. Representatives of the stakeholders were involved in a strategy development process which consisted of four steps:

- Step 1: Describing the current system from a stakeholder's perspective
- Step 2: Exploring possible futures with normative scenarios
- Step 3: Quantifying the effects of actions on goal achievement
- Step 4: Identifying implementable (short-term) actions

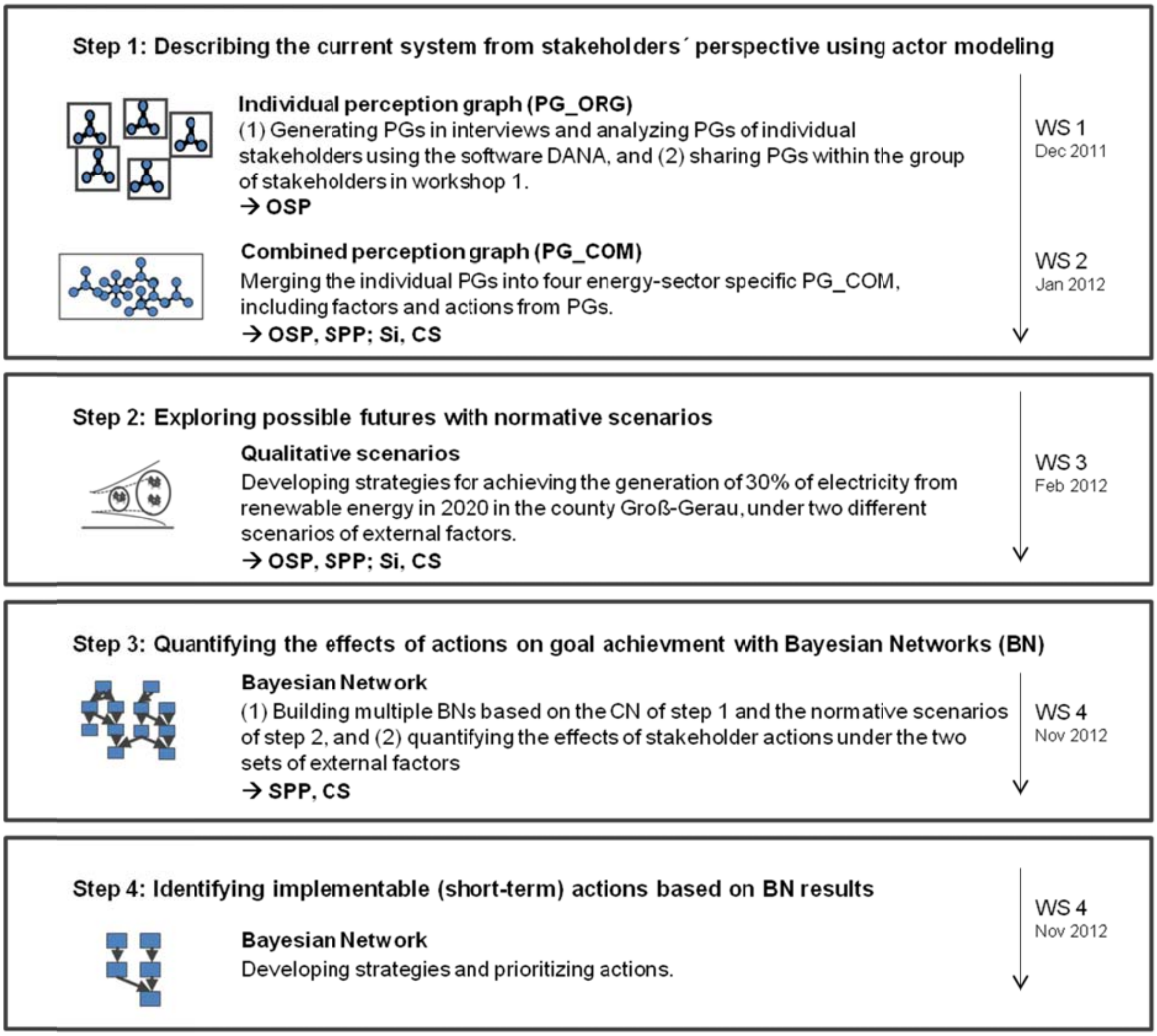

Figure 5-1: Steps of the participatory strategy development process with applied methods, components of social learning that were aimed at (OSP = awareness of each other's sometimes different goals and perspectives, SPP = shared problem perspective, SI = understanding of the stakeholders' interdependence, CS = understanding of the complexity of the management system and conducted workshops (WS) and timeline of the PSD process (based on the figure in [149]).

The entire process took approximately one year to be completed. For a more detailed description of the design and implementation of the strategy development process we refer to Düspohl & Döll (submitted) [121].

The strategy development process was supported by participatory modeling methods, namely actor modeling [121], Bayesian Networks [56, 57], and the development of qualitative normative scenarios [122] (Figure 5-1). Each of the methods aimed at facilitating social learning, particularly with regard to the social-cognitive dimension of social learning.

5.4 Evaluation methods and their application to a participatory strategy development

We applied three methods to evaluate social learning as an outcome of PSD. The first method (referred to as before/after PG in the following text) measures the social-cognitive dimension of social learning by comparing perception graphs of PSD process participants elicited before and after the PSD. A perception graph (PG, Fig 5-2) is a directed a-cyclical graph that represents the problem perception of individual stakeholders by depicting the causal relationships between goals of stakeholder (actor), possible actions of the stakeholder and other stakeholders, the development of external drivers, and relevant factors [119]. PGs were elicited in interviews with representatives of stakeholders 2 to 3 weeks before the first workshop of the PSD in order to understand the diversity of system perspectives and to share them in the first workshop (step 1 in Figure 5-1). To evaluate social learning, elicitation of PGs was repeated 10 to 12 weeks after the last workshop of the PSD process. The social-cognitive components of social learning were determined by comparing stakeholder-specific PGs generated at the beginning (PG_ORG) and the end (PG_UP) of PSD as well as comparing stakeholder-specific PGs with the combined PG_COM, a merge of the individual PGs.

The second method is a questionnaire that was used at the last workshop of the PSD for evaluating the social-relational components of social learning in a quantitative manner. The last method is semi-structured telephone interviews conducted two years after the PSD process. Through interviews, in-depth information regarding changes at the individual level of the stakeholder representatives, the organizational level of the stakeholders, and collaboration triggered by the PSD were obtained. The evaluation of social learning was complemented by analyzing observations and workshop documentation. Observations and interview data were documented through note taking, mostly in combination with audio recording. An overview of the applied methods is shown in Table 1.

Table 5-1: Overview of applied methods to evaluate components of social learning.

Evaluation method applied	Evaluated components for social learning	Description of method application
Before/after perception graph (PG) generated 2 to 3 weeks before the first workshop and 10 to 12 weeks after the last workshop of the PSD	(a) awareness of each other's sometimes different goals and perspectives (social-cognitive)	Identification, in PG_UP of individual stakeholders, of actions and factors that originate from PG_ORG of the other stakeholders
	(b) shared problem perspective (social-cognitive)	Comparison of the overlapping of factors of PG_ORG and PG_UP with the combined PG representing all stakeholders' perspectives
	(c) understanding of the actors' interdependence (social-cognitive)	Comparison of the number of actors identified by stakeholders in PG_ORG and PG_UP
	(d) understanding the complexity of management system (social-cognitive)	Comparison of PG_ORG and PG_UP regarding an increase in identified factors and prospects in the perception of individual stakeholders
Questionnaire distributed at the last workshop of the PSD process	(e) learning to work together (social-relational)	Questions regarding: Development of trust into potential future projects subsequent joint events and workgroup meetings as outcome of the participatory strategy development
	(f) trust (social-relational)	Questions regarding: increase of willingness to share information with other stakeholders understanding of other stakeholders' concerns
	(g) the creation of informal as well as formal relationships (social-relational)	Question regarding: new or more contacts to other stakeholders
Telephone interviews 2 years after the workshop 4 of the PSD	long term evaluation of changes on different levels due to the PSD (mixture of components)	Questions regarding: changes on individual level changes on the organizational level collaborations in the county

5.4.1 Before/after PG

Generation of before/after PG in interview

The strategy development process started with semi-structured interviews with one representative of each stakeholder involved in the PSD process 3 to 2 weeks before the first workshop of the PSD. The interviews were divided into two parts. The first part aimed at getting to know each other and had a rather flexible structure. Possible topics included the position in the stakeholder organization, knowledge about other important actors in the field of renewable electricity generation or the personal motivation for dealing with renewable electricity generation. During the second part of the interview the stakeholder was guided to generate a stakeholder-specific perception graph (PG) on a poster-size paper. The following tasks were given to the interviewee to enable him/her to generate his/her PG.

1) Write the goals of the stakeholders' organization regarding the renewable electricity generation on a colored card and put the goals at the bottom of the poster-size paper. The goals can be sustainability, social, or profit oriented. Formulate goals as nouns.
2) Think of factors that influence the goals and note them on a colored card. Arrange the cards above the goals on the paper.
3) Connect the factors and goals with negative or positive links. The links can best be thought of as "change multipliers": an arrow from factor A to factor B indicates that an increase in A will cause an increase in B when the arrow is labeled with a plus or a decrease when it is labeled with a minus.
4) Identify your own actions of those of other relevant stakeholders that influence the factors. Actions are formulated with a verb.
5) Connect the factors and actions with negative or positive links.
6) Identify factors) that cannot be influenced by stakeholders in the county but have an influence on the development of renewable electricity generation and note them and their likely future development on cards (external drivers or prospects).
7) Connect the factors and prospects with negative or positive links.
8) Talk through the constructed PG and review if the PG represents your (or rather the stakeholder) perception.

The generated PG was converted to a digital version using the software DANA (http://dana.actoranalysis.com/; Bots, 2007) and checked by the interviewee. In total 14 PGs were generated at the beginning of the PSD (PG_ORG, see Figure 5-2a for an example). The individual PGs were merged by the analyst to a combined perception graph PG_COM that was verified by the stakeholders in a workshop (Figure 5-3).

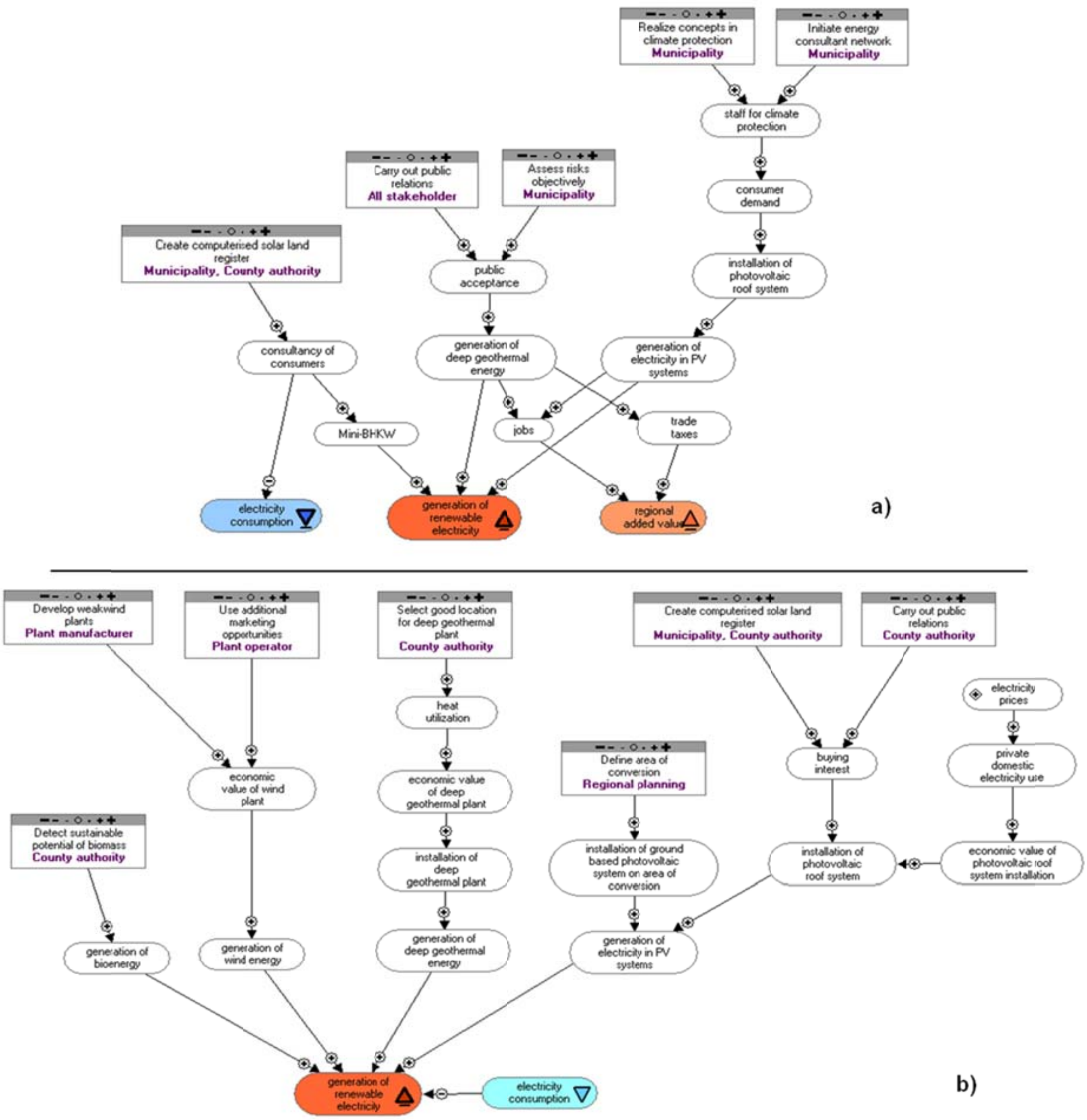

Figure 5-2: Comparison of a) original stakeholder-specific perception graph (PG_ORG) of the municipality that includes goals (colored oval boxes), factors (non colored oval boxes) and actions to be conducted by identified stakeholders (boxes) and b) PG_UP that describe the perception of the stakeholder municipality after taking part in the participatory strategy development process.

The procedure for the construction of individual PGs was repeated at the end of the PSD to generate updated stakeholder-specific PGs (PG_UP; see Figure 5-2b for an example). Eight of the previously interviewed stakeholders were interviewed again 10 to 12 weeks after the last workshop. PG_UP, PG_ORG and PG_COM were compared by the analyst to evaluate social learning as an outcome of the PSD.

Awareness of each other's sometimes different goals and perspectives

Each PG_UP was analyzed regarding the origin of the factors and actions included in the PG_UP. In the analysis factors and actions that were not present in PG_ORG but in PG_UP were considered. If factors or actions originate from the PG_ORG of another stakeholder, this can be interpreted as an awareness of each other's goals and perspectives (Table 5-2). The analysis was performed using the function "relevance" in DANA which enables the identification of common factors and actions between PGs.

Table 5-2: Origin of factors in the PG_UPs of participating stakeholders.

Stakeholder	**Origin of factors (no.)**	**Origin of actions (no.)**
Plant operator	municipality (3), county authority (3), grid operator, environmental agency (4), nature conservation association (2), public utility (2)	county authority (3), environmental agency (1) grid operator (1), municipality (1)
Bank	plant operator (2), county authority (1), environmental agency (3), grid operator (2), municipality (2), public utility (1)	county authority (1), environmental agency (1), grid operator (1)
County authority	bank (3), environmental agency (3), municipality (2), nature conservation association (2), public utility (2)	bank (1), environmental agency (1), municipality (1), nature conservation association (1)
Environmental agency	bank (4), grid operator (1), nature conservation association (1)	plant operator (1), bank (1), municipality (1), nature conservation association (1)
Plant and grid operator	banks (7), county authority (1), environmental agency (3), nature conservation association (2), public utility (1)	county authority (1), environmental agency (3)
Municipality	plant operator (1), banks (2), county authority (1), environmental agency (3), grid operator (1), nature conservation association (2), public utility (1)	county authority (2), environmental agency (2), grid operator (1)
Nature conservation association	banks (1), grid operator (2), municipality (1), public utility (1)	plant operator (1), county authority (2), grid operator (1), environmental agency (3)
Public utility	banks (2), county authority (1), environmental agency (2), grid operator (1), municipality (1), nature conservation association (2)	-

Table 5-2 shows that many factors and actions identified by a stakeholder in PG_UP were mentioned in PG_ORG of other stakeholders, indicating an increase of the awareness of each other´s sometimes different goals and perspectives. Each of the stakeholders included factors and actions originated from the environmental agency's PG.

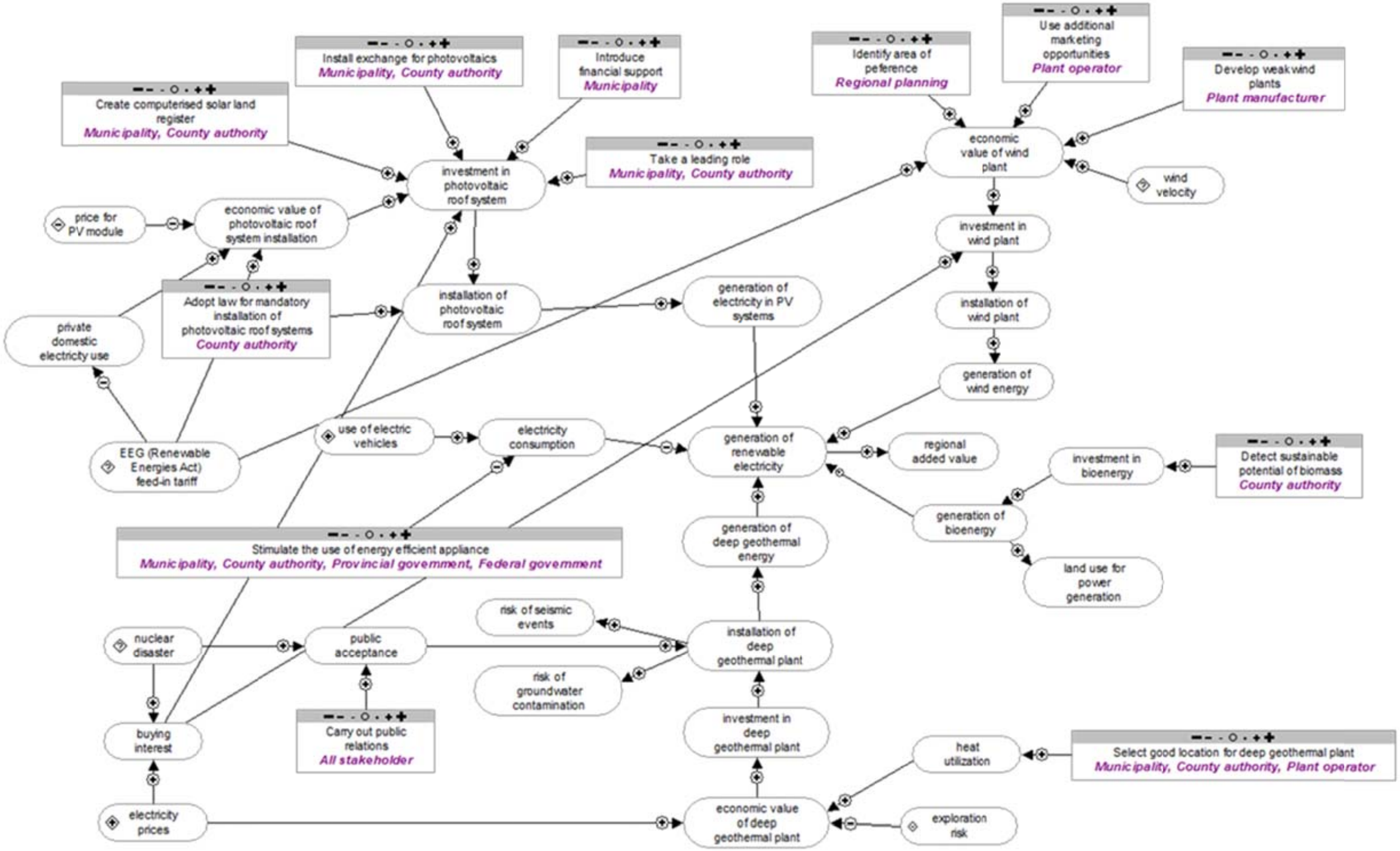

Figure 5-3: Comparison of a) original stakeholder-specific perception graph (PG_ORG) of the municipality that includes goals (colored oval boxes), factors (non colored oval boxes) and actions to be conducted by identified stakeholders (boxes) and b) PG_UP that describe the perception of the stakeholder municipality after taking part in the participatory strategy development process.

Shared problem perspective

The PG_ORG and PG_UP of each stakeholder were compared to PG_COM. The analysis “shared factors” was conducted using DANA. Factors are considered to be shared if they occur in PG_COM and in PG_ORG or PG_UP (Table 5-3). An increase in the percentage of shared factors between PG_ORG and PG_UP is interpreted as an increase in the shared problem perspective.

Table 5-3: Analysis of the shared factors by comparing PG_ORG and PG_UP with PG_COM by application of before/after PG.

Stakeholder	Shared factors in PG_ORG (%)	Shared factors in PG_UP (%)	Difference (%)
Plant operator	31	54	+ 23
Bank	57	62	+ 5
County authority	29	72	+ 43
Environmental agency	48	71	+ 23
Plant and grid operator	31	68	+ 37
Municipality	47	80	+ 33
Nature conservation association	40	64	+ 24
Public utility	23	50	+ 27

The comparison of shared factors in PG_ORG and PG_UP shows an increase in shared problem perspective for all stakeholders. The highest increase in shared factors in the perception was gained by the county authority who was the key stakeholder in the participatory process.

Understanding of the actors' interdependence

PG_ORG and PG_UP were compared regarding the actors that were considered relevant for impacting goal achievement (Table 5-4).

Table 5-4: Actors identified by stakeholders in PG_ORG and PG_UP. (i) are internal actors that were participating in the strategy development process; (e) are external actors who did not participate in the strategy development process by application of before/after PG.

Stakeholder	Actors in PG_ORG	Actors in PG_UP
Plant operator	plant operator (i), bank (i), municipality (i)	plant operator (i), county authority (i), banks (i), plant manufacturer (e)
Bank	bank (i), municipality (i), county authority (i), plant and grid operator (i) provincial government (e), national government (e), media (e)	banks (i), plant and grid operator (i), regional assembly (e)
County authority	plant operator (i), county authority (i), bank (i), municipality (i), plant and grid operator (i), plant manufacturer (e), regional assembly (e)	county authority (i), municipality (i), plant and grid operator (i), chamber of commerce and industry (i), chamber of handicrafts (i), plant operator (i), regional assembly (e)
Environmental agency	bank (i), municipality (i), plant operator (i), farmers (i), national government (e), researcher (e), regional assembly (e), plant manufacturer (e)	plant operator (i), municipality (i), county authority (i), inhabitants (e), regional assembly (e)
Plant and grid operator	plant and grid operator (i), municipality (i), plant operator (i), county authority (i)	plant and grid operator (i), county authority (i), municipality (i), regional assembly (e), provincial government (e), plant manufacturer(e)
Municipality	municipality (i), county authority (i), plant operator (i), regional assembly (e)	municipality (i), county authority (i), plant manufacturer (e), provincial government (e)
Nature conservation association	plant operator (i), grid and plant operator (i), farmers (i), municipality (i), county authority (i), provincial government (e)	municipality (i), county authority (i), plant manufacturer (e), chamber of commerce and industry (i)
Public utility	public utility (i), bank (i), plant and grid operator (i), municipality (i), county authority (i), national government (e)	public utility (i), municipality (i), plant manufacturer (e)

Table 5-4 shows that for almost all stakeholders, the identified significant actor varies significantly between PG_ORG and PG_UP. A decrease of identified actors can be observed in many PG_UP. From this analysis, we can tentatively conclude that a new understanding of the actors' interdependence regarding goal achievement has been gained during the PSD process.

Understanding the complexity of the problem

To evaluate a change in the understanding of the complexity of the problem, PG_ORG and PG_UP were compared against each other regarding changes in the number of factors and prospects (Table 5-5). An increase in the number of factors is tentatively interpreted as an increase of the understanding of the complexity. An increase in the number of identified prospects shows an increase in the awareness of the dependence on external drivers that cannot be influenced by the stakeholders participating in the PSD process.

Table 5-5: Differences in the number of factors and prospects in PG_ORG and PG_UP by application of before/after PG.

Stakeholder	Number of factors, PG_ORG	Number of factors, PG_UP	Difference	Number of prospects, PG_ORG	Number of prospects, PG_UP	Difference
Plant operator	16	24	+ 8	1	5	+ 4
Bank	21	26	+ 5	2	4	+ 2
County authority	24	25	+ 1	0	3	+ 3
Environmental agency	27	31	+ 4	2	2	0
Plant and grid operator	26	31	+ 5	1	6	+ 5
Municipality	19	25	+ 6	0	1	+ 1
Nature conservation association	20	28	+ 8	0	3	+ 3

All stakeholders identified up to 50% more factors in PG_UP than in PG_ORG. and therefore increased their understanding of the complexity of the problems. Nearly all stakeholders identified more prospects in PG_UP than in PG_ORG, which indicates that the PSD led to an increased understanding of the dependence on external drivers.

5.4.2 Questionnaire

A questionnaire was used to evaluate the social-relational components of social learning (indicators (e) to (g) in Table 5-1) in a quantitative manner. The questionnaire was distributed directly at the end of the last workshop. In total 10 responses were collected (n = 10). Two stakeholders only participated in the last two workshops. Therefore, some questions were not relevant for them. Closed questions in the questionnaire were posed using a five-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, 5 = strongly agree).

Learning to work together

We posed two statements in the questionnaire to cover this social learning component. The first statement is "My participation in the strategy development process increased my motivation to advocate regional electricity generation in Groß-Gerau" (Figure 5-4). 4 of the 9 stakeholders agreed to this statement, while 4 neither agreed nor disagreed and 1 disagreed. The second statement is: "Outcomes of the participatory strategy development are inter alia subsequent events and workgroup meetings". 7 out of 10 stakeholders marked this answer as outcome of the PSD in the questionnaire.

Trust

The first statement regarding trust is "My participation in the strategy development process strengthened my trust into potential future projects". 5 out of 9 stakeholders neither agreed or disagreed, while 3 agreed or strongly agreed (Figure 5-4). Stakeholders were also asked if their willingness to share data and information with other stakeholders increased; only one of the stakeholders strongly agreed with this (Figure 5-4). This can be interpreted in two ways: the stakeholders felt that they had been willing to share data and information before the workshop, or there was no increase because, as some stakeholders told us in conversations, it is not transparent how the county authority decides on project partners. However, 5 out of 9 stakeholders agreed or strongly agreed that there had been an increase in the understanding of other stakeholders' concerns which is an important precondition for trust building.

Creation of informal as well as formal relationships

To evaluate this socio-relational component of social learning, we posed a question regarding new or more intensive contacts to other stakeholders gained as a result of the PSD. 8 out of 10 stakeholders marked this statement. This result is supported by additional information collected through the telephone interviews; a joint action was established by the public utility, the bank, and the county authority to offer saving certificates to support photovoltaic projects.

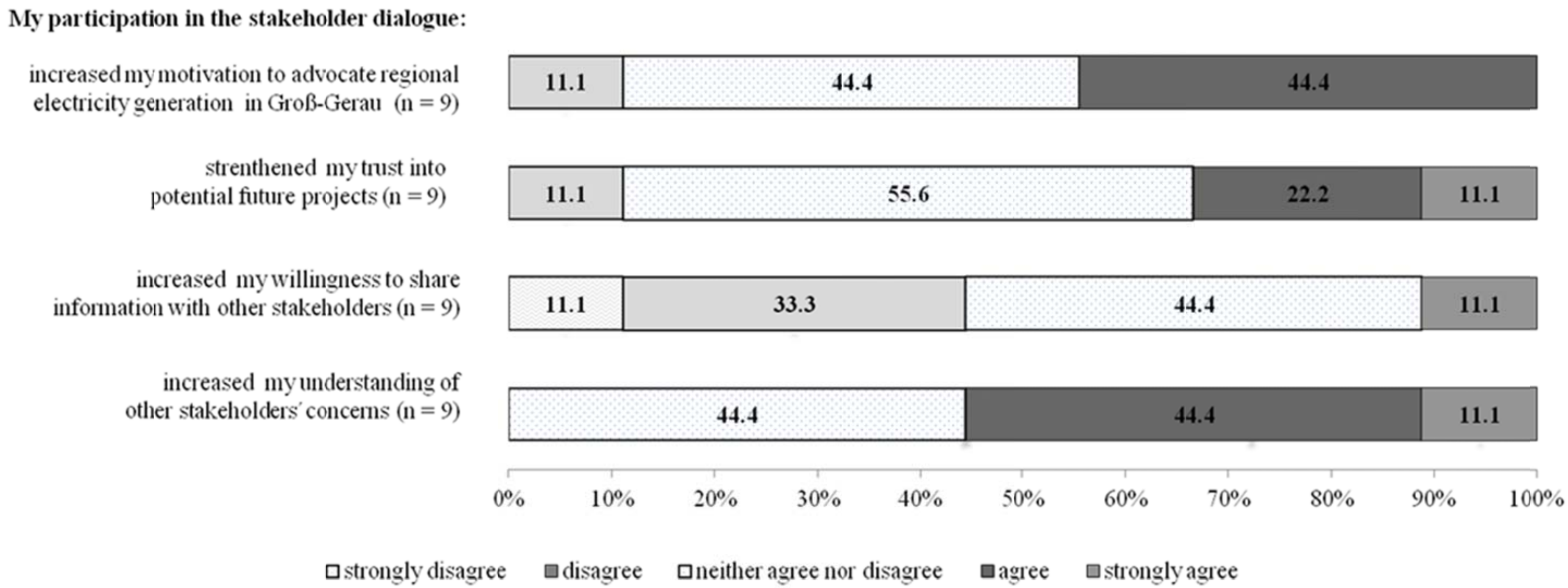

Figure 5-4: Selected results relevant for evaluating social-relational components of social learning from the questionnaire.

5.4.2 Semi-structured telephone interviews

Two years after the end of the PSD, semi-structured telephone interviews were conducted to evaluate the long-term impact of the PSD process. The interview was structured into three components. The first component covered the individual level: Did the participation in the PSD provide knowledge regarding complexity, uncertainty of the system? Could you get to know the different perspectives and finally a shared perspective? Did you made new contacts? The second component asked for changes to the organizational/institutional level of the stakeholders: Could you notice changes in your organization or institution after your participation in the PSD? The third component focused on the aspect of collaboration among the stakeholders after the PSD process: Are you aware of any collaborations or projects that were triggered by the PSD process? In total five interviews were conducted with representatives of the plant operator, bank, environmental agency, municipality, and nature conservation association. The interviews took 5 to 20 minutes.

Table 5-6: Statements of representatives of the stakeholders two years after the PSD regarding changes at individual, organizational, and collaborative levels during the telephone interviews.

Stake-holder	**Individual level**	**Organizational level**	**Collaboration among participating stakeholders**	**Further comments during the interview**
Plant operator	- awareness of uncertainty in the field of renewable electricity generation - new contacts	no changes	collaboration with the bank to finance renewable electricity plants	no
Bank	- awareness of uncertainty in the field of renewable electricity generation - new, intensive contacts with environmental agency, plant operator	set up a project due to the motivation of the representative taking part in the PSD in the field of energy saving	collaboration with plant operator to finance renewable electricity plants	no
Environmental agency	awareness of uncertainty in the field of renewable electricity generation	no changes	no collaboration	no
Municipality	no changes	no changes	no collaboration	maintaining of established stakeholder network and contacts by the county authority failed due to employee turnover in the county authority
Nature conservation association	- awareness of uncertainty in the field of renewable electricity generation - informal contacts	- trust in net and plant operator (deep geothermal energy) - participation in another participatory process	participation in another participatory process	- no maintaining of established stakeholder network and contacts by the county authority failed due to employee turnover in the county authority - get to know valuable methodology during strategy development process

Table 5-6 provides an overview of the qualitative statements of the stakeholders interviewed. Four of the five interviewees pointed out that they became aware of the uncertainty in the field of renewable electricity generation especially with regard to the development of the feed in tariff as key uncertain factor after the PSD. This statement supported the social learning component (d) understanding the complexity of the problem. Three out of the five interviewees mentioned new contacts. On the organizational/institutional level three of the five interviewees could not think of any changes that occurred as a result of their participation in the PSD. The other two stakeholders recognized a change in their organization or institution and connected the change in their own behavior as stakeholder representative to the change in their organization. In one case, the transfer of trust into the organization/institution from the individual level resulted in the participation in another participatory process. The two representatives of the key stakeholder (county authority) left their professional positions after the PSD, and no new representative from the county authority continued collaboration with the stakeholder group involved in the PSD. As a result, the stakeholder network established during the PSD process is not maintained.

5.5 Results

The evaluation results indicate that the PSD was able to support social learning. In the following section we answer research questions 1 to 3 to find out how to best evaluate social learning attained by participatory processes. The research questions are:

1) Did the applied combination of evaluation methods lead to reliable evaluation of the selected components of social learning?
2) What are the advantages and challenges of applying the before/after PG?
3) What aspects of social learning could not be evaluated due to the choice of social learning components?

5.5.1 Research question 1- combination of evaluation methods

Before/after PG

The comparison of PGs generated before and after an intervention is an innovative evaluation method for analyzing the impacts of an intervention like a PSD with regard to social learning. From our experience, we conclude that the analysis of the updated PGs allows analysis of a change in the social-cognitive dimension of stakeholders in a qualitative and quantitative manner. Certainly, differences between the original and the updated PGs cannot be unequivocally attributed to participation in the PSD. As pointed out by a stakeholder representative, he included understanding gained from websites in the Internet to generate PG_UP. To more reliably evaluate social learning achieved by a PSD, it would be necessary to use a control group in the study [150], but this is practically impossible.

Questionnaire

The questionnaire has been shown to be a useful means for analyzing the social-relational dimension of social learning. It provides quantifiable indications and comparisons. Certainly, the results gained in this case study lacks statistical significance due to the small sample size.

Some results gained from the questionnaire may be biased. According to Kok & van Vliet (2011) [10], respondents might want to give more socially wanted answers or the impression that their time was well spent in the participatory process. They tend to avoid stating extreme opinions in the questionnaire [153]. The tendency to choose neutral answers can be influenced by the design of the questionnaire. In this questionnaire, the Likert scale that consists of five options was used. The mid-range of the scale is a 'neutral' option (i.e. neither agree nor disagree) which was selected by most respondents as "safe choice". The effect is that it is sometimes difficult to draw clear conclusions about some aspects of social learning, for example trust among stakeholders (more than half of the respondents neither agreed nor disagreed that the participation in the participatory strategy development strengthened trust in future projects).

Certainly, not all social-relational components could be fully evaluated by the questionnaire. For instance, trust among stakeholder was not fully explored also because the development of trust was not the focus of this study. In addition, while establishing trust among stakeholders is important, it is recognized that researchers can only partly influence factors that support trust development [154].

Likewise, the choice of answers by respondents was also influenced by the way how questions were formulated in the questionnaire. Taking the example of trust development again, the question asked if there was an increase in the willingness to share information with other stakeholders. Stakeholders who had already had a high willingness to share information before the participatory process should have chosen "totally disagree" or "disagree" due to the fact that the willingness did not grow or increase. Instead, they answered "neither agree nor agree" or "totally agree".

Telephone interviews

The telephone interviews aimed at the evaluation of long-term effects on the stakeholder representative, the stakeholder organizational and the collaborative level. The results showed that the PSD affected each of the different levels. With the selected questions for the stakeholder representative and the stakeholder organizational level, it was not possible to link the answers to the seven social learning components.

Some interviewees struggled to remember actually participating in any specific events of the PSD; they were not able to articulate details about the activities in the workshops after 2 years. One participant responded that he felt poorly equipped to answer the questions since he were no longer representing the same stakeholder. Distortion effects depend on the content and the context of the memorized information and can be profound after longer periods [155].

5.5.2 Research question 2 – advantages and challenges of before/after PG

The before/after PG is an innovative approach to detect components a) to d) of social learning with a) awareness of each other's sometimes different goals and perspectives; (b) shared problem perspective; (c) understanding of the actors' interdependence; (d) understanding of the complexity of the management system. The application of the before/after PG requires in comparison to the distribution of a questionnaire more time and effort. The advantage of the before/after PG is the possibility to circumnavigate the problem that stakeholders are according to some studies only partly aware of their own perspectives and how they change over time [156, 157]. By visualizing the perception in a PG the stakeholder is able to see the change over time.

A challenge is the evaluation of the awareness of each other´s sometimes different goals and perspectives (component a)) with the before/after PG. It was done by comparing factors and actions in PG_UP with those in PG_ORG. The results indicate the inclusion or integration of goals and factors originated from other stakeholders into the PG of an individual, but not the awareness as meant by Pahl-Wostl & Hare (2004) [133] of other stakeholders´ goals and perspectives. The evaluation of the understanding of the actors' dependence can be criticized in a similar way.

5.5.3 Research question 3 – choice of social learning components

The evaluation carried out in this study focused on social learning by individuals (i.e. representatives of stakeholders). It did not include the impact of the PSD process on wider learning which occurs among organizations. According to Reed, Evely, Cundill, Fazey, Glass et al. (2010) [54], social learning needs to describe a phenomenon that demonstrates a change that goes beyond individuals or small groups to become situated within wider units or communities of practice. Wiek, Talwar, O'Shea, & Robinson (2014) [158] call this phenomenon a societal effect.

5.6 Lessons learned and outlook

The aim of this article was to evaluate social learning as a result of a PSD using a combination of three quantitative and qualitative methods. In particular, a new method for evaluating social-cognitive components of social learning was applied that involves the determination of changes in the problem perception due to the PSD. A questionnaire was used to evaluate socio-relational components. Semi-structured interviews as well as workshop documentation, and observation complemented these methods. The components of social learning considered were: (a) awareness of each other´s sometimes different goals and perspectives, (b) shared problem perspective, (c) understanding of the actors´ interdependence and (d) understanding the complexity of management system, (e) learning to work together, (f) trust, and (g) the creation of informal as well as formal relationships. The study shows that the applied methods are suitable for evaluating components of social learning, and that the PSD was successful in strengthening social learning. Many previous studies claimed that social learning did occur but these claims were not verified. Our study, even though not without limitations and challenges, seems to give those claims an empirical base.

There is a need for an improved methodology for the evaluation of social learning. Our suggestions for improved evaluation of each of the seven components of social learning are provided in Table 5-7. In the future stakeholder representatives could be asked to generate perception graphs of other stakeholders to indicate his or her awareness of the goals and perspectives of the others. To measure a shared problem perspective or convergence of perspectives, a scoring table as suggested by Van der Wal, De Kraker, Offermans, Kroeze, Kirschner et al. (2014) [159] can be used. The method is based on the assumption that individual perspectives can be described with a set of beliefs based on archetypical Cultural Theory perspectives. A change of beliefs due to a participatory approach can be detected by comparison of the perspectives before and after the approach. Additionally, playing board games is a possible method for evaluating the understanding of actors' interdependence, complexity of management system, and learning to work together [133]. Besides, we recommend that the questionnaire not only covers the social-relational dimension of social learning, but also social cognition. The results gained by the questionnaire could be compared to the results generated by the before/after PG. Our suggestions for specific questions can be found in Table 5-7.

Table 5-7: Overview of methods for evaluating social learning gained by experience from the PSD of the described case study and literature.

Component of social learning	**Evaluation method**	**Questions that can be included in questionnaire**
(a) awareness of each other's sometimes different goals and perspectives	Letting stakeholder representatives draw PG of other representative of stakeholders	How has your awareness of the different goals and perspectives of the other stakeholders changed during your participation in the strategy development?
(b) shared problem perspective	- Before/after PG - Measuring convergence of perspectives with scoring table [141]	Have you gained a shared perspective on the problem at the end of the participatory process?
(c) understanding of the actors' interdependence	Playing board game based on an actor-based model and interpret the game by an independent psychologist [131]	Do stakeholders need to collaborate to solve the problem? If so, which stakeholders would need to collaborate?
(d) understanding the complexity of management system	- Updated PG (this article) - Playing board game based on an actor-based model and interpreting the game by an independent psychologist [131]	Did the participatory process show the complexity of the management system?
(e) learning to work together	Playing board game based on an actor-based model and interpreting the game by an independent psychologist [131]	Can you think of joint actions of participating stakeholders?
(f) trust		Would you share information with other stakeholders participating in the strategy development? Could you imagine addressing conflicts during the participatory process? Do you have the feeling that you got to know the other stakeholders better and understand their perspectives?
(g) the creation of informal as well as formal relationships		Did you get new contacts during the participatory process? Could you intensify contacts during the participatory process? Are the relationships informal or formal?

Representatives of stakeholders who have learned through the participation in a PSD provide an important basis for triggering societal effects that go beyond the stakeholder level. They can influence policymaking and governance that accelerates the generating and societal embedding of renewable electricity and lead to spin-off collaborative actions within extended stakeholder networks. Finally, this study leads us to endorse Wiek et al.' s framework and methodological scheme for capturing societal effects of participatory processes [158]. This model takes into account direct and tangible as well as indirect and less tangible effects. Effects include quality products, knowledge gains, increased decision-making capacity, enhanced networks, and transformational changes.

6

Building trust while modeling with stakeholders as requirement for social learning

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6.1 Abstract

Many participatory modeling approaches (PMA) aim at supporting social learning among stakeholders. Trust is one important requirement for successful social learning. We relate our experiences trying to improve participatory modeling with local experts in the identification of a region-specific strategy for renewable electricity generation. The PMA was implemented in Groß-Gerau, a county in Germany. In the case study, we evaluated an innovative combination of methods that support the region-specific strategy identification. The methods applied are actor modeling (AM), scenario development and Bayesian Networks (BN). The evaluation of the case study and informal information shows that stakeholders do not trust each other. What would have been the design of the PMA that could positively influence the building of trust among stakeholders? Based on a literature analysis, we identified five factors that positively influence trust building among stakeholders in a PMA. These factors are: (1) mutual understanding of individual stakeholders' values, (2) enhanced fair,

balanced, trustworthy communications during the PMA, (3) skilled facilitation and mediation, (4) availability of a core of mutual knowledge and (5) minimization of stakeholder turnover impacts. Finally, we present an enhanced design of the PMA to support trust building among stakeholders. This design includes an intensive get-to-know each other of the stakeholders and the engagement of a skilled facilitator during the PMA.

6.2 Introduction

In many cases, participatory modeling approaches (PMA) aim at enhancing social learning among stakeholders [23]. Social learning is a process of reframing and convergence of stakeholders´ perspectives on the problem, possible solutions and implementation by collaboration [160]. One important requirement for successful social learning is trust among participating stakeholders [5]. According to practitioners and researchers, trust is needed for effective decision making [160]. Hahn et al. (2006) [162] determined that trust building and knowledge generation are the central components for collaboration. Trust is central to teamwork, leadership, and organizational culture. Perhaps trust is so coveted because the effects of distrust can be destructive. Fear, scepticism, and opposition are among the most notable consequences of a lack of trust in organisations [161].

But what is trust? Trust can be defined as the expectation that others will act in a way that is agreeable for a stakeholder without the possibility of the stakeholder to intervene. According to Davenport et al. (2007) [163], "two key underlying assumptions emphasize that trust (1) requires a certain degree of dependence and (2) accompanies a particular set of expectations".

A standard tool to promote trust is the participation of stakeholders, like in a participatory modeling approach to support a decision making process. However, this participation does not necessarily result in trust [164]. Indeed, stakeholders stated that they did not trust each other in our own experience evaluating a PMA used to design a region-specific strategy for renewable electricity generation. In retrospective, we ask: What would have been the design of the participatory modeling approach that could positively influence the building of trust among stakeholders?

This paper aims at giving an answer to that question and introducing an enhanced design of a PMA using knowledge gained from a literature study. To achieve this aim we give in the next section an overview of the design of the case study. We then present the factors that influence trust. In the final section, we discuss the results gained from literature analysis and conclude by highlighting components that could be integrated in an enhanced design of a PMA to support the building of trust among stakeholders.

6.3 Design of a PMA

Germany is aiming at achieving energy for consumption (electricity, heat, fuels) to be supplied with up to 20 % of renewable energy in 2020. On a larger scale, regions and cities are asked to support that national goal by transforming their electricity generation systems. In the county of Groß-Gerau, 30 % of the electricity consumption from renewable energy by the year 2020 is targeted to be produced within the county. The current generation of renewable electricity (data from 2007) is less than one percent of the electricity consumption. The potential contribution of renewable electricity is about 20 times higher than the electricity consumption in 2007 (Table 1-1).

To support the identification of an implementable strategy for achieving the 30 % goal of the county, we set up a PMA aided by an innovative combination of participatory methods (i.e. actor modeling, participatory scenario development and Bayesian Network modeling). A total of 15 stakeholders were involved in the PMA, covering a broad range of experts who are representatives from the private sector, politics, research and non-governmental organizations. The PMA, comprising interviews and workshops with identified stakeholders, started with a meeting with the key stakeholder to address the design of the PMA.

The conceptual design of the PMA is shown in Figure 4-3. It included four steps in which participatory methods and communication tools were combined. The steps are:

- Step 1: Describing the current system from a stakeholder's perspective using actor modeling (AM)
- Step 2: Exploring possible futures with normative scenarios
- Step 3: Quantifying the effects of actions on goal achievement with Bayesian Network (BN) modeling
- Step 4: Identifying implementable (short-term) actions with BN modeling.

The entire strategy development process took approximately one year to be completed. During this period, we conducted in total fourteen interviews and four half-day workshops addressing step 1 to 4. Step 1 was reached in workshop 1 and 2, while step 2 started in workshop 2 and ended in workshop 3. Step 3 and 4 were executed in workshop 4. A more detailed description of the PMA is elaborated by Düspohl &Döll [151].

By adopting a PMA, we also aimed at social learning among the stakeholders as well as supporting an active stakeholder network for further collaboration to accelerate electricity generation in Groß-Gerau. The achievement of this goal was assessed at the end of the PMA. Based on the PMA evaluation results and informal discussions with stakeholders, we found out that there was a lack of trust among the stakeholders which might limit the possibility for the collaborative development of a realizable management strategy.

6.4 What are factors that influence trust?

Trust is required for social learning [5] and effective decision making [161]. Therefore, trust building should become one of the central components for collaboration (cf. [160]). With a view to the outcome of our PMA, the question is: What would have been the design of the participatory modeling approach that could positively influence the building of trust among stakeholders? To answer this question we first identify factors that influence trust among stakeholders by conducting a literature search.

6.4.1 Mutual understanding of individual stakeholder values

The availability of information about the values of a stakeholder is one of the important factors that influence trust building among individuals. In the case that information about the values and objectives of others regarding the PMA are lacking, emotions and heuristics fill the knowledge gap. According to Schwarz & Clore (1983) [165], people use their momentary affective states as information. These ''affect-as-information'' heuristics and similarity with the individual have a significant influence on personal trust judgments [166] and the level of trust [164]. Although studies have shown that not all trust judgments regarding another person are rational and knowledge based decisions, individuals who have different backgrounds and obtain different values and objectives are seen as unknown, therefore less trustworthy [167]. On the contrary, when the objectives and expectations of an individual are well known, the trust decision is built on existing evidence or associations, and individuals are perhaps judged as trustworthy.

6.4.2 Enhanced fair, balanced, trustworthy communications

The mode of communication during a PMA has an impact on the development of trust among the stakeholders. PMA facilitators should clearly outline the scientific questions being asked, the methods and knowledge produced, how this knowledge informs policy, and most importantly how the knowledge created can be integrated with the goals of stakeholders [164]. Having been informed about what will happen with the results at the beginning of a PMA, stakeholders may be less likely to express skepticism [163]. In addition the limits and uncertainty connected to modeling results should be transparently addressed. During a PMA, communication with stakeholders should be undertaken in such a way that the stakeholders gain the feeling that people listen to them instead of forcing them with rules and legislation [162]. Likewise, the creation of a trustful informal setting like a flexible network provides an opportunity for repeated interactions and communication, thus supporting trust development [131, 162].

6.4.3 Skilled facilitation and mediation

Effective communication asks for a skilled facilitator. The personal qualities of the facilitator, and his or her ability to build trust and establish alliances, are important. The facilitator should be well trained in group interactions and have appropriate skills and expertise in participatory approaches [147], including leadership. As pointed out by Pahl-Wostl et al. (2008) [116], "the role of leadership is to generate the trust needed to engage in an open debate and leave entrenched positions." Leadership does not include imposing one view on a group. Instead, it guides the group members (i.e. participating stakeholders) to express and share their views. This is relevant for establishing collaborative leadership, which can be described as "convening" the stakeholders and caring about an ongoing partnership, rather than controlling the process.

6.4.4 Availability of a core of mutual knowledge

Knowledge has been shown to exist as a factor correlated with trust [168]. If the level and type of knowledge held by one stakeholder is not consistent with the level and type of knowledge important to another stakeholder, then a potential disconnection between these two ''knowledge systems'' may decrease trust [164].

6.4.5 Minimization of stakeholder turnover impacts

During a PMA, stakeholders are responsible for bringing the views of their organizations to the process and giving their organizations feedback on the outcomes of the process. As they gain a sense of belonging to the multi-stakeholder approach, trust and understanding can develop. However, the transfer of this trust and understanding to the organizations of the representatives is a critical point. Over-reliance on individual representatives seems to be risky for a successful PMA because individuals may leave their organizations and thus the PMA [147]. Stakeholder turnover can be compared with the situation in an organization, in which Davenport et al. (2007) [163] identified staff turnover as one important constraint to building trust.

6.5 Discussion and conclusion

Five factors that influence trust building among stakeholders in a PMA have been identified in the previous section based on the analysis of literature. These factors play a role in contributing to the success of a PMA. However, not all of these factors can be influenced by the organizing researchers in a PMA. Trust is built or not built during interactions among stakeholders inside as well as outside of the PMA. It should be recognized that:

- To gain information about the values of different stakeholders might be a challenge in a PMA due to the complexity of values. Höppner (2009) [169] state that values are often complex and multi-dimensional and are likely to vary across and within stakeholder groups.
- The development of mutual knowledge depends on the personal interest of the involved stakeholders. Motivating stakeholders to gain mutual knowledge about a complex issue is, according to Siegrist & Cvetkovich (2000) [168], a complex task and cannot be ensured during a PMA.
- There is no possibility to influence stakeholder turnover during a PMA. One possible solution to prevent the loss of trust could be making sure that there is some back-up representation (with associated familiarity and trust) for each essential stakeholder entity in the PMA.

Taking these concerns into account, we propose the integration of the following components in the enhanced design of the PMA implemented in our case study.

- A skillful facilitator could be engaged throughout the entire PMA. The facilitator of the PMA could explain in a clearer and more explicit way regarding the scientific questions being asked and the outcomes gained during the PMA. The importance of a collaborative leadership can be highlighted.
- At the beginning of workshop 1, an interactive get-to-know-each-other session can be organized to provide an opportunity for participating stakeholders to share their values and to express their expectations regarding the PMA. The subsequent workshops could take place in the working environment of the participating stakeholders, and not always at the location of the key stakeholder. This approach helps to enhance the development of personal relationships among the stakeholders and therewith trust-building outside the PMA.
- Best-practice examples from other counties or regions in Germany which have comparable aims regarding their renewable electricity generation

could be presented and shared with the participating stakeholders, showing the possibility to achieve common goals.

- Throughout the PMA, stakeholders could be informed about actual developments in the current problem field to support mutual knowledge generation.

We are aware that additional efforts at building trust require extra resources and more intensive engagement. Last but not least, trust should be handled with care because it is much easier to destroy than to generate. As mentioned by Gray et al. (2012) [164], negative events have much greater impact on self-reported trust than positive events do. Trust can be easily destroyed in such situations as (1) making decisions in the traditional top-down, expert-driven style, without listening to the stakeholders [163], (2) providing information about values of stakeholders and about the PMA in general to external staff not involved in the PMA [5], (3) avoiding face-to-face communication – instead prefer communication via e-mail or other mediums [170], (4) trying to hide uncertainty, limits or even risks of new technologies or of modeling results [171, 172] and (5) using incorrect information during the PMA [173]. These situations should be avoided during a PMA that requires trust for successful social learning.

7

Synthesis

7.1 Introduction

Transdisciplinary research is a new research mode aiming at generating robust knowledge from academia and practice on how to solve complex real world problems. In this case study the real world problem was to develop a strategy for the transformation of the electricity generation system of a county in Germany with participation of relevant institutional stakeholders. The question is how participatory strategy development processes as transdisciplinary research project needs to be designed, implemented and evaluated. This thesis therefore focused on the documentation of the design and implementation of the participatory strategy development and the analysis of the impacts of the participatory process on its participants (stakeholders). Four research questions were defined (Chapter 1) and addressed (Chapter 3 -6). The research questions are:

(1) What do we know about the application and applicability of Bayesian Networks (BN) as a participatory modeling tool in transdisciplinary research?
(2) How can a participatory process with its applied methods support the identification of a strategy for the acceleration of renewable electricity generation?
(3) What are measurable components of social learning and how can the participatory process be evaluated with regard to social learning and its components?
(4) How can the participatory process be improved with regard to trust development among stakeholders?

For the first question, we reviewed the recent literature on participatory BN modeling in environmental management (Chapter 3). The review provides a solid knowledge basis for researchers (with experience in either BNs or participatory methods) and practitioners who consider using BNs in participatory processes. For the second question, we implemented and evaluated a participatory strategy (PSD) process for promoting renewable electricity generation in a German county, in which a new combination of participatory methods was applied (Chapter 4). In a next step, components of social learning as a core outcome of the PSD were evaluated using a combination of quantitative and semi-quantitative methods, including an innovative method to determine changes in the problem perception of the participants (before/after PG) (Chapter 5). The evaluation of the PSD showed that stakeholders did not trust each other. Trust is requirement for social learning. The conducted literature review identified five factors that influences trust building in a PSD. Key findings of this PhD thesis are summarized in Table 7.1 in section 7.2. In the next sections of this chapter the contribution to science and the limitations of the study (Chapter 7.3) are given. Chapter 7.4 provides the contribution to practice (renewable electricity generation). An outlook on further research on this topic is given in Chapter 7.5.

7.2 Main results and conclusions

Table 7-1: Overview of research questions and main results and conclusions.

Research question	Main results and conclusions
What do we know about the application and applicability of BNs as a participatory modeling tool in transdisciplinary research? (Chapter 3)	*59 case studies* describe the application of BNs as participatory modeling method. They were mainly applied in water management and conservation management. The average number of stakeholder involved in participatory BN modeling was about 10, with a minimum of 2 and a maximum of 23. In less than half of the case studies (26 out of 59) stakeholders from outside of academia participated in the BN modeling. Stakeholders were only partly involved in the stages of BN modeling. Most case studies used a combination of different input data (outputs of numerical models, stakeholder knowledge, statistical and observation data) to fill in CPTs. The construction, validation and testing of a BN were estimated to take 20 person-months. BNs are proposed to have the potential to work as a decision support system in practice. Only three case studies mentioned a successful implementation. *Recommendations for participatory BN modeling:* Expectations of the participants should be elicited and openly addressed in order to avoid misunderstandings regarding aims and scopes of a project. The identification of variables should aim at identifying variables that are controllable and observable. Before the CPTs are constructed some simplification of the network structure is required. More than one stakeholder should be consulted for CPT construction to increase trust in the modeling results. BN model should be reviewed and tested by an experienced modeler and also by the stakeholders. *Evaluation criteria* for participatory BN modeling: (1) structured process to deal with complex planning; (2) integration of knowledge from diverse sectors; (3) visual presentation of cross-benefits; (4) description and decrease of uncertainty in prognosis; (5) limitation of complexity; (6) support communication and social learning; (7) link of research to policy; (8) identification of lack of knowledge for integration. *Strengths and limitations of BNs:* + Integration of various knowledge, explicit consideration of uncertainty, variety of possible input data, transparency, short run times, support of communication and learning. - Limited representation of spatial variability, temporal dynamics and feedbacks, difficulty to elicit conditional probabilities, reliability of expert beliefs and BN modeling results, cognitive difficulties with probabilities, lack of precision of BN models and results. The literature review points out that BNs potentially are a core method of transdisciplinary research and knowledge integration with a thorough contemplation of the strengths and limitations of BNs. The intensive participation of stakeholders in BN construction and application increases the transparency and credibility of BN modeling results. As a consequence this increases the buy-in of the modeling results to support the identification of mutually agreed implementable and coherent strategies. This includes the generation of conditional probability tables by experts in a workshop to make their beliefs about causal relationships in the BN transparent to the other stakeholders .

Table 7-1: Overview of research questions and main results and conclusions (continued).

Research question	Main results and conclusions
How can a participatory process with its applied methods support the identification of a strategy for the acceleration of renewable electricity generation? (Chapter 4)	The participatory *strategy development consisted out of four steps*: (1) describing the current system from a stakeholder perspective; (2) exploring possible futures; (3) quantifying the effects of actions on goal achievement and (4) identifying implementable (short-term) actions. The execution of the steps was supported by selected participatory methods: actor modeling (AM) supported step (1), qualitative normative scenarios step (2) and BN modeling step (3) and (4). Evaluation results showed that the AM was able to fulfill the requirements (1) to map out diversity, (2) to grasp the complexity of the problem. Qualitative normative scenario development fulfills (3) to take into account the uncertainty in the problem field. Criterion (4) to support the identification of implementable strategies was only partly fulfilled by BNs due to the lack of credibility of BN model and results The applied combination of methods was able to achieve the first three objectives, even if the modeling methods are missing some technical aspects like modeling dynamics or feedbacks. The fourth objective was only partly achieved in the PSD.
What are measurable components of social learning and how can the participatory process be evaluated with regard to social learning and its components? (Chapter 5)	Based on literature, the *components of social learning* considered were: (a) awareness of each other´s sometimes different goals and perspectives, (b) shared problem perspective, (c) understanding of the actors´ interdependence and (d) understanding the complexity of management system, (e) learning to work together, (f) trust, and (g) the creation of informal as well as formal relationships. Components (a) to (d) of social learning were evaluated by the innovative *before/after PG*. The method has the advantage by visualization to avoid the sometimes missing awareness of the change of stakeholders´ perspectives during a participatory process. A challenge is that the evaluation methods before/after PG not clearly refer to the awareness of stakeholders different goals and perspectives and the actors´ dependence. Components (e) to (g) were evaluated using a *questionnaire* at the end of "REG Groß-Gerau". Two years after the PSD *telephone interviews* were conducted. The results of the telephone interviews showed that the PSD had effects mainly on the individual stakeholder representative level, partly on the organizational level of the stakeholder and rarely on collaborations among participating stakeholders. Most of the individual stakeholders gained knowledge about the uncertain development of external factors. The combination of methods (consisting of (1) determination of changes in the problem perception of the participants using perception graphs generated before and after the PSD (before/after PG), (2) a questionnaire distributed at the last workshop of the PSD and (3) semi-structured telephone interviews conducted two years after the PSD) was able to evaluate the selected components of social learning. A further component "triggering societal effects beyond the stakeholder level" should be included in the component selection for the evaluation of social learning.

Table 7-1 Overview of research questions and main results and conclusions (continued).

Research question	Main results and conclusions
How can the participatory process be improved with regard to trust development among stakeholders? (Chapter 6)	Based on evaluation results throughout the PSD, we found out that trust among stakeholders plays an important role. Trust building had not been focused on in our PSD, Nevertheless, we conducted a literature analysis and identified five factors that positively influence trust building among stakeholders in a PSD. *These factors are:* (1) mutual understanding of individual stakeholders' values, (2) enhanced fair, balanced, trustworthy communications during the PSD, (3) skilled facilitation and mediation, (4) availability of a core of mutual knowledge and (5) minimization of stakeholder turnover impacts. One possibility to prevent the loss of trust in the case of stakeholder turnover could be making sure that there is some back-up representation (with associated familiarity and trust) for each essential stakeholder in the PSD. Best-practice examples from other counties or regions in Germany which have comparable aims regarding their renewable electricity generation could be presented and shared with the participating stakeholders, showing the possibility to achieve common goals. Throughout the PSD, stakeholders could be informed about actual developments in the current problem field to support mutual knowledge generation. Not all of these factors can be influenced by the organizing researchers in a PSD. Trust is built or not built during interactions among stakeholders inside as well as outside of the PSD. It should be recognized that: (a) to gain information about the values of different stakeholders might be a challenge in a PSD due to the complexity of values. (b) The development of mutual knowledge depends on the personal interest of the involved stakeholders.

7.3 Scientific contribution

The research goals of this study (Chapter 1) have been reached. The PhD thesis presents the design, implementation and evaluation of a four-step PSD supported by a combination of participatory methods in the face of social learning among the participating stakeholders. The effort taken for the implementation of the combination of two main transdisciplinary modeling methods (AM and BN) and participatory qualitative normative scenario development is in a good balance to achieve the research goal.

During the case study the researcher collected valuable experiences in participatory modeling. From the author perspectives it is an important scientific contribution to share these experiences and provide an overview of the lessons learned during the case study regarding the design of a PSD and the application of the combination of participatory methods. Table 7-2 provides an overview of recommendations how to improve different aspects of a PSD like coordination of a PSD, providing a good workshop atmosphere, the application of the modeling and evaluation methods and the role of the scientists.

Table 7-2: Overview of lessons learned and recommendations for conducting a PSD.

Aspect of PSD	Experience in PSD "REG Groß-Gerau"	Recommendations
Coordination of the PSD	No clear formulated responsibilities of the researchers and the key stakeholder in the PSD.	Draft a coordinative plan among the researchers and key stakeholder at the beginning of the PSD including the responsibility for public relations of the PSD in the media.
Atmosphere during the PSD to initiate trust development among stakeholders	A little stiff atmosphere during the workshops in the location at the county authority.	Organize an interactive get-to-know-each-other session to provide an opportunity for participating stakeholders to share their values and to express their expectations regarding the PSD. The subsequent workshops could take place in the working environment of the participating stakeholders, and not always at the location of the key stakeholder. Present best-practice examples from other counties or regions, showing the possibility to achieve common goals.
Application of methods	The application of the combination of methods which are new to the stakeholders, overload the stakeholder capacity to learn about the methods within the timeframe of the PSD.	Use BNs directly from the beginning of the PSD to describe the different stakeholder perspectives in a PG_IND and to combine the perspectives in a PG_COM.
	Stakeholders had the feeling that their own perspectives were not understood by the other stakeholders.	Organize a short feedback session after the presentation of each PG_IND.
	Stakeholders did not refer to the BN modeling results when selecting the possible actions for a strategy to reach the 30% goal of the county	A more intensive construction and application procedure to work on BNs: 1) Experts would be asked to develop the conditional probabilities together with the analyst before a workshop. 2) Experts explain exemplarily their beliefs about conditional probabilities to the stakeholders during a workshop.
	Power relations among the stakeholders were not sufficiently analyzed.	The case study would have benefited from the application of methods from social science to analyze the power relations among the stakeholders.

Table 7-2: Overview of lessons learned and recommendations for conducting a PSD (continued).

Aspect of PSD	Experience in PSD "REG Groß-Gerau"	Recommendations
Role of scientists	Scientists play five roles in a PSD: facilitator, modeler, process coach, recorder and gate keeper. Another role is the owner of scientific knowledge in the field of renewable electricity generation. Due to the background of the participating scientists, this role was not sufficiently fulfilled.	Be aware of those five roles. Include scientists with different backgrounds to fulfil each role properly.
Evaluation of the PSD	The number of stakeholders (sample size) was too small to make statistical significant statements with regard to the questionnaire.	Initiate a control group that does not take part in a PSD.
	Difficulties to evaluate the understanding of the other stakeholders´ perspectives	Let stakeholders draw perspectives of the other stakeholders as a PG.
	No capturing of the triggered societal effects	Use Wiek et al.' s framework and methodological scheme for evaluating societal effects of a PSD [158].

7.4 Contribution to renewable electricity generation in Groß-Gerau

The second goal of the case study "REG Groß-Gerau" was the identification of implementable and mutually agreed strategies to support the promotion of the renewable electricity generation. Table 7.2 shows the identified actions according to the energy sectors and responsible stakeholders.

The identified strategies were evaluated from the stakeholders to reflect their understanding and to be coherent. However they were evaluated to be not concrete and realizable. We therefore recommend a further workshop where the identified actions are intensively discussed and concretized.

Further the PSD provided a platform for crosssectoral communication about the issue of renewable electricity generation in the county of Groß-Grau. The PSD supported the understanding of the complexity, especially of the uncertainty, in the system of interest. The PSD helped to identify gaps in the present knowledge e.g. about the effects of measures taken in the field of renewable electricity generation. We therefore recommend the execution of subsequent transdisciplinary research projects that fill these gaps with knowledge from inside and outside of academia.

Table 7-3: Actions categorized by each energy sector and dedicated to responsible stakeholders to support an accelerated implementation of renewable electricity generation in Groß-Gerau identified by stakeholders in the last workshop of the PSD.

Energy sector	**Action**	**Responsible stakeholders**
All	Public relation work (energy fair)	All stakeholders
	Consult energy consultants	Energy suppliers
	Focus on integrated energy systems (power and heat)	Power company
	Encourage energy saving	County, municipalities and power company
PV	Obligation for PV systems	Municipalities
Wind	Define priority areas for wind energy	Not defined
Deep geothermal energy	Promote public support of deep geothermal energy	County, municipalities and power company

7.5 Outlook and further research

The case study described in the thesis focused on the design and implementation of a PSD and its evaluation as well as on the evaluation of social learning during the PSD. To contribute to the ongoing effort of doing transdisciplinary PSD processes and to overcome limitations we experienced, further research could take the following steps

- The application of methods of social science to analyze the personal relationships among the participating stakeholders (e.g. analysis of the recorded dialogues between stakeholders during the workshops) would allow gaining a deeper understanding of e.g. the power relations among stakeholders and the effects these power relations have on the outcomes of the PSD.
- In the described case study one representative from each stakeholder involved in the PSD were selected by the key stakeholder EKC. The EKC chose the stakeholders based on earlier contacts with the representative. One problem with this procedure is that there is the tendency to select ´spokesperson´ based on his or her ability to present the stake/ position of the stakeholder he or she is representing: good and firm negotiators who try to get the biggest piece of the pie. The competences associated with that way of working are almost opposite to the ones needed for a fruitful social learning process where people rise above their own interest. A detailed analysis of the personality requirements of a "good" stakeholder representative could be investigated in the future.
- Future research should define the degree of system knowledge that is needed to make useful quantitative statements and possibly to support the choice of appropriate strategies by using conditional probabilities. To get a deeper understanding about the applicability of the participatory methods it would be interesting to apply the method in a problem field with a higher degree of system knowledge.
- Furthermore, a problem field with more conflictual perspectives than in our case study would allow analysing the ability of the participatory methods to reduce tension among stakeholders and achieve compromise.

The PSD is a recursive and iterative process that needs to be continually adapted as the process evolves.

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Appendices

Appendix A: Documentation of semi-structured interviews

A-1 Informationen für die Stakeholder vorab des Interviews

Der Kreis Groß-Gerau hat das naturräumliche Potenzial, seinen Strombedarf zu 100% aus Strom zu decken, der im Landkreis aus erneuerbaren Energien erzeugt wird. Die Aufgabe ist es nun, Wege zu einer raschen Nutzung dieses Potenzials zu identifizieren. Dies kann nur gemeinsam durch die relevanten Akteure geschehen. Daher sollen deren Wissen und Ideen in einem partizipativen Prozess transparent gemacht und integriert werden. In einem Interview mit den einzelnen Akteuren, also mit Ihnen, werden ihre Interessen am Ausbau erneuerbarer Energien und mögliche Handlungen aus Ihrer Sicht identifiziert.

Das Interview nimmt ca. 1,5 – 2,5 Stunden Ihrer Zeit in Anspruch. Gemeinsam werden wir ein kausales Netzwerk erstellen, der Ihre Wahrnehmung/Interesse zum Thema „Mobilisierung der Erneuerbaren Energien im Kreis Groß-Gerau“ widerspiegelt. Wir sprechen bei diesem Netzwerk von Ihrem Wahrnehmungsgraphen. In Ihrem Wahrnehmungsgraphen verbinden sich Ihre Ziele durch Ursache-Wirkungsbeziehungen mit möglichen Handlungen und Faktoren. Nach dem Interview wird das Netzwerk in die Software DANA (Dynamic Actor Network Analysis) eingegeben und mit dieser Software analysiert. Abbildung A1 ist ein Beispiel für einen Wahrnehmungsgraphen zum Thema Lärm mit seinen Komponenten in DANA.

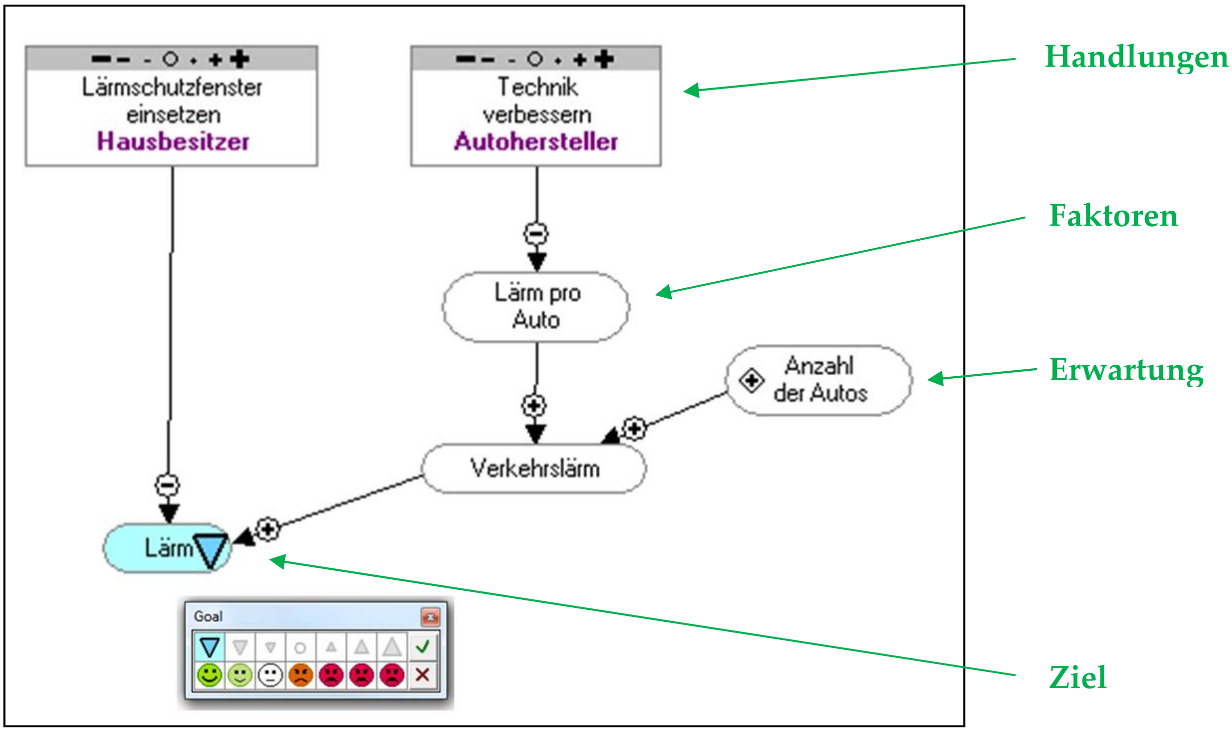

Abbildung A1: Elemente eines Wahrnehmungsgraphen zum Thema „Lärm"/„Lärmbelästigung".

Das Beispiel zeigt die Problemwahrnehmung eines Hausbesitzers zum Thema Lärmbelästigung durch den Verkehr vor seinem Haus. Ziel des Hausbesitzers ist es, den Lärm zu verringern. Das Ziel wird in dem Beispiel durch den Faktor „Verkehrslärm" beeinflusst. Der Hausbesitzer erkennt zwei mögliche Handlungen die Auswirkungen auf sein Ziel haben. Er selbst kann die alten Fenster in seinem Haus austauschen und durch Lärmschutzfenster ersetzen. Desto mehr neue Fenster er einbaut, desto weniger Lärm ist im Haus zu hören. Die andere Handlung aus Sicht des Hausbesitzers ist die Verbesserung der Technik durch die Autohersteller. Diese Handlung würde den Lärm, der je Auto produziert wird, verringern. Der Hausbesitzer erwartet eine Zunahme an Autos. Daran geknüpft ist eine Zunahme des Verkehrslärms.

Während des Interviews erstellen wir Ihren Wahrnehmungsgraphen zum Ausbau der Erneuerbaren Energien auf Papier unter Berücksichtigung der vorgestellten Elemente. Die Elemente des Graphen sind wichtig für die semiquantitative Analyse in DANA. Gerne bringe ich Ihnen während des Interviews die einzelnen Symbole näher und gebe Ihnen weitere Informationen.

Ich freue mich auf das Interview und bin gespannt auf Ihre Wahrnehmung!

Meike Düspohl
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Telefon: 069 - 798 40220

A-2 Semi-strukturierter Interviewleitfaden

Einleitung

Vielen Dank für Ihre Zeit mit mir ein Interview durchzuführen. Wie Sie bereits dem kurzen Informationsblatt entnommen haben, geht es in diesem Interview um den Ausbau Erneuerbarer Energien bzw. die Entwicklung nachhaltiger und umsetzbarer Handlungsstrategien. Um einen möglichst umfangreichen und realistischen Eindruck über die Erneuerbaren Energien in Groß-Gerau zu bekommen, ist eine große Auswahl an Akteuren und die Berücksichtigung Ihrer Wahrnehmung als Akteur … notwendig.

Daher würde ich gerne Ihre persönliche Wahrnehmung als Experte zum Thema Ausbau der Erneuerbaren Energien in GG ermitteln. Gemeinsam mit den Wahrnehmungen der anderen Akteure wird Ihre Wahrnehmung die Situation der Erneuerbaren Energien vervollständigen. Für das Experten-Interview sind zwei Teile vorgesehen. Zum einen möchte ich mit Ihnen über den Ausbau der EE im Kreis Groß-Gerau sprechen. Im zweiten Teil erarbeiten wir gemeinsam Ihren Wahrnehmungsgraphen zum Ausbau der EE in Hessen. Ist Ihnen dieser Ablauf recht? Wir können gerne zwischendurch eine Pause machen. Wir haben hier Kekse und Wasser. Sagen Sie Bescheid falls Sie eine Pause brauchen. Auch ich melde mich, wenn meine Akkus leer sind und ich gerne eine Pause machen möchte.

Ab jetzt Notizen für den Wahrnehmungsgraphen machen!

Teil A: Als Einstieg in das Thema würde ich gerne zu Ihrer Person erfahren. Sie sind als … tätig.

- Erzählen Sie doch von Ihren Aufgaben/Verantwortungen?
- Wie sind Sie zu dieser Position gekommen?
- Welchen Bezug haben Sie zu Erneuerbaren Energien oder zum Ausbau EE?
- Wie ist die Position Ihrer Organisation im Hinblick auf den Ausbau EE?
- Was würde sich durch den Ausbau der EE ändern? (Welche Vorteile oder Nachteile bringen die EE Ihnen?)
- Wer sind Ihrer Meinung nach wichtige Akteure für den Ausbau der Erneuerbaren Energien?
- Können Sie sich Konfliktsituation vorstellen, die sich bezüglich des Ausbaus der EE ergeben?
- Wovon hängen diese Konfliktsituationen ab?

- Wie könnte man die Konfliktsituationen lösen?
- Gibt es Lücken / ungelöste Probleme bezüglich des Ausbaus der EE? (30´)

Teil B: Einführung in die Erstellung des Wahrnehmungsgraphs

Jetzt geht es darum, nachdem wir im Laufe des Gesprächs Ihre Wahrnehmung erörtert haben, Ihre in ein Schaubild einfügen. Dazu schauen wir uns zunächst ein Beispiel eines solchen Wahrnehmungsgraphs an. Diese Abbildung kennen Sie vielleicht aus dem Informationsblatt, dass ich Ihnen zu geschickt habe. Sie sehen hier ein Beispiel zum Verkehrslärm. *Kurze Erläuterung des Graphs.* Haben Sie Fragen in Bezug auf die Erstellung des Wahrnehmungsgraphs?

Ich bitte Sie nun ein Schaubild zu erstellen, das Ihre Wahrnehmung zum Thema Ausbau Erneuerbare Energien widerspiegelt indem Sie Ihre Ziele, mögliche Handlungen und Faktoren die Ihre Ziele beeinflussen, mit kausalen Verknüpfungen (Einfluss-Pfeile) verbinden. Wir erstellen die Abbildung auf diesem Papier. Später werde ich Ihre Wahrnehmung in ein Software-Programm (DANA) einfügen. Es ähnelt dann dem Wahrnehmungsgraphen des Hausbesitzers in dem Informationsblatt. In DANA werde ich Ihre Wahrnehmung analysieren und Ihnen anschließend die Ergebnisse der Analysen zukommen lassen.

Dazu schreiben Sie bitte die einzelnen Elemente auf Karten und pinnen Sie auf das Papier. Dabei sollten Sie folgende Struktur des Wahrnehmungsgraphs berücksichtigen: am Ende stehen die Ziele, am Anfang die Handlungen und dazwischen die Faktoren. Daraufhin zeichnen Sie die kausalen Verknüpfungen zwischen den einzelnen Elementen. Die einzelnen Karten haben folgende Bedeutung:
Grüne Karte: Ziele
Orangene Karte: Handlung
Gelbe Karte: Faktoren (inklusive Erwartungen)

Fragen um die Erstellung des Wahrnehmungsgraphs anzuleiten (Immer mit Bezug auf das Gespräch am Anfang des Interviews, da er in diesem Gespräch bereits Ziele, Faktoren, etc. genannt hat)

- Bedenken Sie die Situation der Erneuerbaren Energien, z.B. an die technischen Fortschritte, gesetzliche Regulierungen, Möglichkeiten der Erneuerbaren Energien.

- Was sind Ihrer Meinung nach die wichtigsten Ziele die im Bereich Erneuerbare Energien von Ihrer Organisation/Unternehmen/Institution erreicht werden sollen? Denken Sie dabei nicht nur an ökologische Ziele sondern auch an soziale und wirtschaftliche Ziele. Um ein Ziel zu formulieren machen Sie sich deutlich was Ihnen wichtig ist und wie diese Ziele erreicht werden können (wie der Hausbewohner, für den der Lärm eine große Rolle gespielt hat und er wünschte, dass der Lärm reduziert wird.) Bitte schreiben Sie jedes Ziel auf eine grüne Karte (Nomen).
- Nächster Schritt: Überlegen Sie bitte welche Faktoren diese Ziele beeinflussen? Bitte verbinden Sie die Faktoren und Ziele mit positiven bzw. negativen Einfluss-Pfeilen (Positiv bedeutet: mehr Autos führen zu mehr Lärm, weniger Autos führen zu weniger Autos. Negativ bedeutet: Mehr Autos führen zu weniger Lärm, weniger Autos führen zu mehr Lärm.)
- Durch welche Handlungen Ihrer Organisation/Unternehmen/Institution werden diese Faktoren beeinflusst? Denken Sie dabei an Handlungen durch Sie selbst bzw. durch andere Akteure? Bitte nutzen Sie zur Formulierung von Handlungen Verben (Fenster ersetzen) und schreiben Si e darunter wer der Akteur ist. (Handlungen sind autonom und können nicht durch andere Faktoren, Erwartungen oder Handlungen beeinflusst werden).
- Alternative: Welche eigenen Handlungen (der Organisation/des Unternehmens/der Institution) sehen Sie, um Ihre Ziele (Interessen) zu erreichen? Und welche Faktoren werden durch diese Handlung beeinflusst? Bitte beschreiben Sie die Kausalbeziehungen zwischen den Handlungen und den Faktoren und Ihren Zielen (Interessen). Gibt es Unsicherheiten in den Kausalbeziehungen? [Die Kausalbeziehungen mit Pfeilen darstellen und die Unsicherheit notieren]
- Welche anderen Akteure sind im vorgestellten Problemfeld einflussreich? Mit welchen Handlungen beeinflussen diese Akteure die von Ihnen genannten Faktoren und ihre Ziele (Interessen)? Bitte beschreiben Sie die Kausalbeziehungen zwischen den Handlungen und den Faktoren und Ihren Zielen (Interessen). Anmerkung: Falls keine anderen Akteure genannt werden, werden Akteure vorgeschlagen und nach deren Einfluss und Handlungen gefragt [Handlungen (inkl. der Akteure) und neuen Faktoren auf Karten notieren und mit Pfeilen darstellen]
- Was denken Sie, inwieweit wirken sich Entwicklungen anderer Faktoren außerhalb des Gebietes der erneuerbaren Energien auf Ihre Ziele aus?
- Akteure können in der Umsetzung von Handlungen begrenzt sein. Bitte weisen Sie auf die Handlungen hin, die Ihrer Ansicht nach möglich sind.

(e.g. – to ++: action could slightly decrease, remain at the same level as today, slightly increase or increase)

- Ihre Ziele besitzen eine große Relevanz. Können Sie zusätzlich Ihre Ziele erneut beschreiben? Ich würde Ihre Ziele gerne Wort für Wort aufschreiben. Also, wofür stehen die Ziele in den einzelnen Boxen?
- Würden Sie ein oder mehrere Ziele für wichtiger erachten als andere? Können Sie die Ziele nach Wichtigkeit bitte priorisieren? 1 bedeutet das wichtigste Ziel
- Nun folgt eine abschließende Anpassung der Verknüpfungen (ausgehend von der mittleren Handlungsänderung und mittleren change multipliers): Gibt es Handlungen die schwächer oder stärker sind in ihrer Wirkung als andere Handlungen? Welche Handlungen (Entscheidung) würde Ihrer Ansicht nach den Ausbau EE am stärksten fördern?
- Ich werde nun Ihren Wahrnehmungsgraphen in eigenen Worten zusammenfassen und würde Sie bitten mich zu korrigieren. Habe ich Ihre Wahrnehmung richtig wiedergegeben?
- Wenn Sie sich den Graphen erneut anschauen, spiegelt er Ihre Ansicht wieder? Oder möchten Sie etwas korrigieren?
- Abschließend möchte ich Sie fragen, warum die genannten Ziele für Sie wichtig sind.
- Ich werde die Ergebnisse in DANA übertragen und würde Ihnen gerne die Analyse-Ergebnisse zu kommen lassen, so dass wir sicher sind Ihre Wahrnehmung richtig erfasst zu haben.

Foto des Wahrnehmungsgraphen!

Vielen Dank für die Erstellung des Wahrnehmungsgraphen.

- Erlauben Sie mir noch eine Frage: Inwieweit würden Sie sich selbst als repräsentativen Akteur im Bereich … einschätzen? Können Sie andere Akteure identifizieren, die eine höhere Repräsentanz besitzen? (MD, 07.11.2011)

Appendix B: Example of interview documentation

Weiter unten finden Sie das semi-quantitative kausale Netz, das Ihre Perspektive als Akteur „BUND“ auf das Thema „nachhaltiger Ausbau der Stromerzeugung aus erneuerbaren Energien“ im Kreis Groß-Gerau widerspiegelt. Bitte überprüfen Sie, ob das von mir mit der Software DANA erstellte kausale Netz in dieser Form von Ihnen autorisiert werden kann. Wir planen dieses Netz als Kommunikationsgrundlage im ersten Workshop zu nutzen. Bitte achten Sie bei der der Überprüfung auf:

– Vollständigkeit der Handlungen und Ziele (Seite 4)
– Richtige Zieldefinition (Seite 2 und 3)

Sie können Ihre Anmerkungen und Verbesserungsvorschläge gerne mit der Kommentarfunktion im pdf einfügen. Eine weitere Möglichkeit ist die handschriftliche Korrektur, die Sie mir bitte per Fax oder eingescannt bis zum 25.11.2011 zukommen lassen. Meine Kontaktdaten sind dazu die Folgenden:

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Nun folgt zunächst eine kurze Erläuterung zu der Software DANA (http://dana.actoranalysis.com), der Software mit dem ich die kausalen Netze erstelle und analysiere. Danach sehen Sie wie ich die von Ihnen genannten Ziele in DANA umgesetzt habe. Das kausale Netz des Umweltamtes Riedstadt wird durch die Legende verständlich so wie auch durch die ausführlichen Erklärungen der einzelnen Elemente. Letztere finden Sie im Anhang.

DANA
Das Programm Dynamic Actor Network Analysis (DANA) ist ein graphenbasiertes Tool und wurde für die Policy-Analyse entwickelt (Bots et al. 1999, 2000). Mit DANA ist es möglich, Sichtweisen von Akteuren in Form von kausalen Netzen zu modellieren. Diese Graphen können als causal maps bezeichnet werden und repräsentieren die Beziehungen zwischen Akteurshandlungen, externen Einflüssen und Zielen von Akteuren (Bots 2007). Aufgrund der semi-quantitativen Datenstruktur können die erstellten kausalen Netze analysiert werden. So ist es beispielsweise möglich, mit DANA optimale Handlungsstrategien von Akteuren auf Grundlage der subjektiven Akteurswahrnehmung zu berechnen.

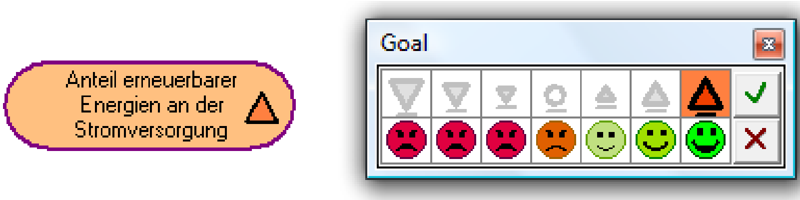
Umsetzung der Ziele des Akteurs „BUND“ in DANA

Ziele werden über die gewünschte Änderung eines Zielfaktors definiert. Smileys und Frowneys (Smileys mit herabhängenden Mundwinkeln) zeigen welche Änderungen (Tabelle 1) des Zielfaktors durch den Akteur erwünscht und nicht erwünscht sind. .

Symbol	Bewertung durch den Akteur
	große Freude/Zustimmung
	mittlere Freude/Zustimmung
	leichte Freude/Zustimmung
	gleichgültig
	leichte/r Ablehnung/Ärger
	mittlere/r Ablehnung/Ärger
	große/r Ablehnung/Ärger

Ziel 1

In dem Gespräch erklärten Sie, dass es Ziel des BUND Kreisverband Groß-Gerau ist den Anteil erneuerbarer Energien an der Stromversorgung im Kreis Groß-Gerau zu erhöhen. In DANA wird dieses Ziel durch den folgenden Zieldialog dargestellt:



In Worten beschreibt der Zieldialog, dass sich Sie als Akteur BUND Kreisverband Groß-Gerau sehr freuen, wenn der Anteil der Erneuerbaren Energien sehr stark steigt. Entsprechend dazu empfinden sie mittlere Freude, wenn der Anteil mittel stark steigt und schwache Freude bei geringem Anstieg. Hingegen sind mittel stark verärgert, wenn der Anteil erneuerbarer Energien an der Stromversorgung gleichbleibt und stark verärgert bei einer Abnahme der erneuerbaren Energien.

Ziel 2

Für Sie als BUND ist es wichtig, dass der Artenschutz (auch eines Ihrer Ziele) nicht unter dem Ausbau der erneuerbaren Energien leidet. Ihr Ziel 2 wird in DANA mit dem folgendem Zieldialog beschrieben.

Verbal ausgedrückt bedeutet der Zieldialog mit seinen Smileys und Frowneys, dass Sie sich mittel stark freuen wenn der Artenschutz im Kreis Groß-Gerau gleichbleibt oder zunimmt. Bei einer etwaigen Abnahme des Artenschutzes sind Sie als Akteur stark verärgert.

Ziel 3

Das Ziel 3 beschreibt den für Sie als BUND wichtiger Flächenverbrauch für die Energieerzeugung. Sie möchten diesen Flächenverbrauch auch bei der Stromerzeugung aus erneuerbaren Energien möglichst gering halten.

Der graphische Zieldialog beschreibt Ihr Ziel indem Sie sich mittel stark freuen, wenn der Flächenverbrauch abnimmt. Auch wenn der Flächenverbrauch in geringem Maße zu nimmt ist Ihnen dies gleichgültig. Nimmt der Flächenverbrauch hingegen mittel bzw. sehr stark zu sind Sie mittel stark bzw. stark verärgert.

Ziel 4

Bei Ziel 4 handelt es sich um die regionale Wertschöpfung. Sie möchten die regionale Wertschöpfung im Kreis Groß-Gerau steigern.

Der graphische Zieldialog beschreibt Ihr Ziel indem Sie sich mittel bzw. schwach stark freuen, wenn die regionale Wertschöpfung stark bzw. mittel stark zunimmt. Wenn die regionale Wertschöpfung in geringem Maße zu nimmt ist Ihnen dies gleichgültig. Nimmt die regionale Wertschöpfung hingegen ab sind Sie stark verärgert. Eine gleichbleibende regionale Wertschöpfung ärgert Sie mittel stark.

Ihr kausales Netz in DANA

Nach unserem Gespräch habe ich den von uns erstellten Wahrnehmungsgraphen in DANA implementiert. Ihr kausales Netz finden Sie auf der nächsten Seite. Bitte bedenken Sie die Bedeutung der einzelnen Elemente (Handlungen, Attribute, Erwartungen, kausale Verknüpfungen und Ziele) in DANA.

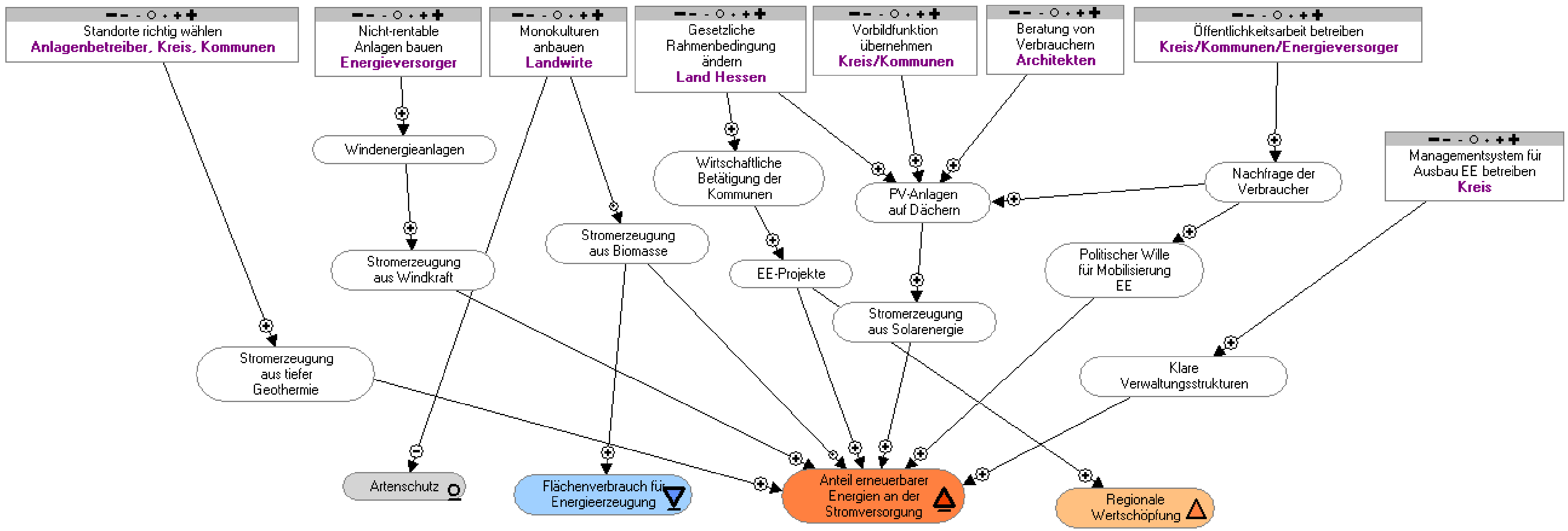
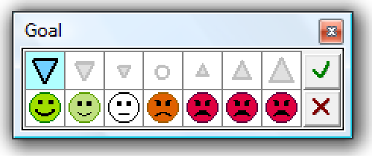
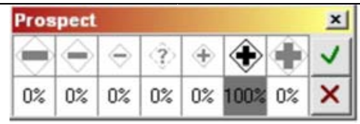
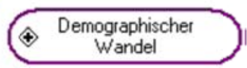


Abbildung B1: Kausales Netz des Akteurs „BUND“ in DANA.

Legende

Element in DANA	Symbol	Beschreibung
Ziel	 	Ausrichtung Dreiecksspitze zeigt Zu- oder Abnahme des Zielfaktors; Größe des Dreiecks gibt die Stärke der Zu-oder Abnahme; Smileys und Frownies (Smileys mit hängenden Mundwinkeln) zeigen die Bewertung durch den Akteur
Handlung		Neutrale Tätigkeiten mit dem jeweiligen ausführenden Akteur
Faktor		Faktoren sind Elemente, die von Handlungen oder anderen Faktoren beeinflusst werden können
Verknüpfung		Ursache-Wirkungsbeziehung: **Positive Verknüpfung:** Zunahme in einem Faktor bedeutet Zunahme des Zielfaktors und umgekehrt. **Negative Verknüpfung:** Abnahme in einem Faktor bedeutet Zunahme im Zielfaktor.
Erwartung	 	Erwartungen sind in DANA von Akteuren nicht beeinflussbare Entwicklungen, die auf Systemfaktoren einwirken

Appendix C: Documentation workshop 1

Tabelle C1: Planung des Workshops 1.

Workshop 1 am Freitag den 9.12.2011 - Austausch der Wahrnehmung der einzelnen Akteure				
Ziele: Kennenlernen der einzelnen Teilnehmer Gemeinsame Erarbeitung von Strategien zur Mobilisierung der Erneuerbaren Energien im Stromsektor im Kreis Groß-Gerau				
Zeit	Thema	Aktion	Materialien	Verantwortlich
10:00	Begrüßung durch 1. KBO	-	-	1. KBO
10:15	Willkommen und Einführung in das Programm des Tages	Gibt es Fragen zum Ablauf des Tages? Anmerkungen vorab?	Laptop und Beamer	Meike Düspohl
10:30	Vorstellung der einzelnen Akteure	Pro Akteur: 3-4 Minuten Zeit die wichtigsten Punkte des kausalen Netzes aufzugreifen und zu erläutern Was zeichnet mich als Akteur aus?	Laptop und Beamer	Alle Akteure
11:30	Analyseergebnisse (Auswertung der Interviews)	Präsentation der 1. Ergebnisse: Was sind die bisher genannten Strategien der einzelnen Akteure?	Laptop und Beamer	Meike Düspohl
12:00	Postersession mit Verpflegung (aktive Mittagspause)	Austausch der Akteure anhand ihres Posters: 20 Minuten Anwesenheit am eigenen Poster 3 Runden 1. Runde: SW Rüsselsheim, NABU, EKC, ÜWG; 2. Runde: BUND, GGV, Regionalentwicklung GG, Magistrat Mörfelden-Walldorf; 3. Runde: AWS, GV Bischofheim, UA Riedstadt, Bauernverband	Poster an Stellwänden, Imbiss	Alle

13:00	Einführung in die Methode des World Café	Schritte und Etikette des World Café	Beamer und Laptop	Meike Düspohl
13:10	World Café		Beschreibbare Tischdecken Teilnehmer verteilen sich an den aufgestellten Tischen. Nach einer gewissen Zeit sind die Teilnehmer aufgefordert den Tisch zu wechseln	Petra Döll, Stefan Leimbach, Gregor Steiger und Meike Düspohl, alle
14:15	Präsentation der Ergebnisse des World Cafés	Kurzer Bericht (ca. 5 Minuten) durch den Tischmoderator über die Ergebnisse der einzelnen Tische		Petra Döll, Stefan Leimbach, Gregor Steiger, Sina Frank und Meike Düspohl
14:45	Reflektion und Feedback	Wie fanden Sie die Methode bezüglich der Ergebnisse? Was würden Sie anders machen wollen?	Reflektionskarte	Anleitung: Meike Düspohl Alle
15:00	Ende der Veranstaltung	Wir wünschen Ihnen ein gutes Wochenende!		

Tabelle C2: Dokumentation des World Cafés in Workshop 1.

Energiesektor (Tisch)	Hemmnis	Maßnahme	Ziel
Wind	Fehlende Windhöffigkeit im Kreis Groß-Gerau	Investitionen in Regionen außerhalb des Kreises (Rhein-Main) in Windenergieanlagen bzw. Repowering von Windkraftanlagen. Dies bedeutet eine andere Zieldefinition.	Anteil der EE an der Stromversorgung in GG erhöhen (Stromimport)
	Fehlende Frontmänner/Frontfrauen	Technisch wirtschaftliche Expertise einholen (Windmessungen konkret, Renditeerwartungen	
	Flächenverbrauch	Konzentration der Anlagen in Windparks	
	Komplikationen während Genehmigungsverfahren	Frühzeitige Einbindung des Vogelschutzes	
Photovoltaik	Fehlende Kapazität der Einspeisepunkte		

	PV-Anlagen auf Denkmalgeschützten Häusern		
	Konkurrenz zur Nahrungsmittelproduktion bei Freiflächen	Ausweisung von Konversionsflächen (Kiesseen, Deponien und Randstreifen von Autobahnen und Schienenwegen)	
	Fehlende Dachflächen für PV-Anlagen	Kommunale Satzung ändern, Anlage kann auch von anderem Investor betrieben werden, Installation einer Solarbörse (Bürger, die einen Bauantrag stellen sollen gefragt werden, ob sie Interesse an einer PV-Anlage haben. Wird diese Frage bejaht, werden die Daten (der Dachfläche etc.) an die Börse weitergeleitet und die dort teilnehmenden Firmen können sich um dieses Projekt bewerben)	
Biomasse	Potenzial für die Nutzung von Biomasse nicht bekannt (Bioabfall, Waldholz)	Gesamtaufkommen im Kreis erfassen	
	Fehlendes Wegesystem zur Belieferung der Biogasanlagen (Konflikt mit Spaziergängern)	Ausbau des landwirtschaftlichen Wegenetzes	
	Umweltschutz/Artenschutz	Keine Monokulturen anbauen	

Appendix D: Documentation workshop 2

D-1: Information zu den kausalen Gesamtnetzwerken in Vorbereitung auf Workshop 2.

Auf den folgenden Seiten finden Sie die kausalen Gesamtnetzwerke als Ergebnisse der Interviews und des ersten Workshops. Diese kausalen Netze integrieren die von Ihnen genannten Faktoren, Erwartungen und Handlungen in jeweils einem Gesamtnetz für die Energiesparten Biomasse, tiefe Geothermie, Photovoltaik und Windkraft. Zudem habe ich teilweise als Analystin Handlungen und Faktoren ergänzt. Diese werde ich im zweiten Workshop erläutern.

Bitte überprüfen Sie, ob Sie den von mir mit der Software DANA erstellten kausalen Netzen (S. 2-5) Faktoren oder Handlungen hinzufügen möchten. Bitte denken Sie daran, dass DANA in den nächsten Workshops der Visualisierung dient. Die Legende und die Erläuterungen (S. 6-8) dienen als Hilfestellung zum Nachvollziehen der einzelnen Netze. Sie können Ihre Anmerkungen und Verbesserungsvorschläge am besten handschriftlich einfügen und zum Workshop am 20.01.2012 mitbringen.

Zur besseren Lesbarkeit der Netze weisen sie eine feste Struktur auf. Diese gestaltet sich wie folgt:

- Der zentrale Faktor des jeweiligen Netzes ist farblich gekennzeichnet.
- Die weiteren Faktoren sind im kausalen Gesamtnetz thematisch strukturiert und wie in der in folgenden Abbildung angeordnet.

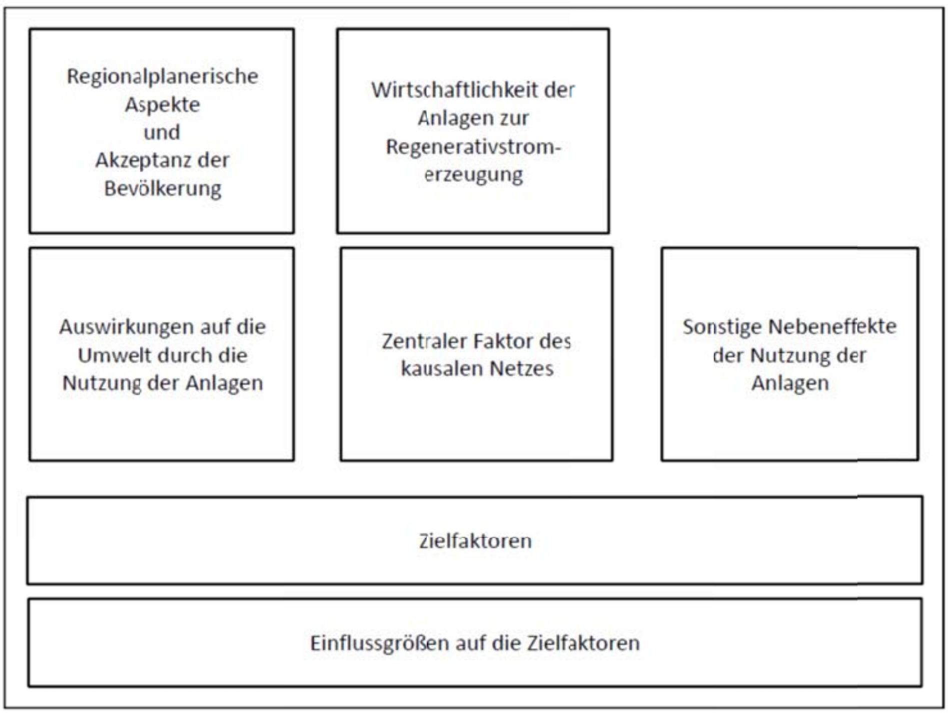


Abbildung D1: Struktur der kausalen Gesamtnetze.

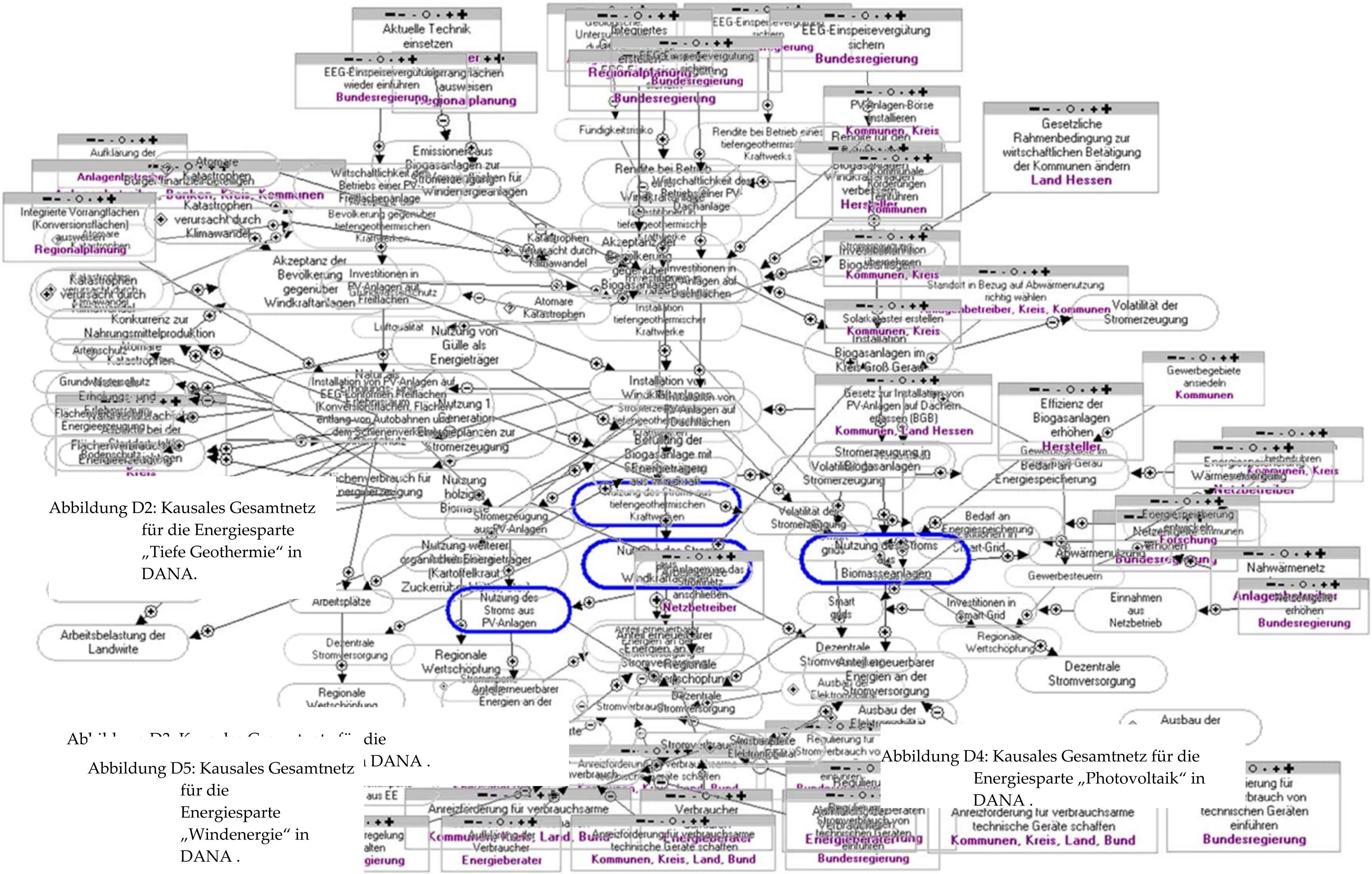


Abbildung D2: Kausales Gesamtnetz für die Energiesparte „Tiefe Geothermie“ in DANA.

Ab... D3: K... für die ... DANA .

Abbildung D5: Kausales Gesamtnetz für die Energiesparte „Windenergie“ in DANA .

Abbildung D4: Kausales Gesamtnetz für die Energiesparte „Photovoltaik“ in DANA .

2.Workshop 2 am Freitag den 20.1.2012 – Erarbeitung abgestimmte kausale Gesamtnetze und Start der Szenarienentwicklung				
Ziele: Erarbeitung abgestimmter kausaler Gesamtnetze und Storylines für normative Szenarien				
Zeit	Thema	Inhalt/Handlung	Materialien	Verantwortlich
9:00	Begrüßung der TN	Willkommen, Vorstellung des Workshopsteams, Programm des Tages	Flipchart mit Herzlich Willkommen und Zielen des Tages	PD, MD
9:10	Vorstellung der neuen Akteure (KSK GG, HWK FRM)	Pro „neuer" Akteur: 3-4 Minuten Zeit die wichtigsten Punkte des kausalen Netzes aufzugreifen und zu erläutern „Alten" Akteure stellen sich kurz mit Namen und Institution vor	Laptop und Beamer	Alle Akteure
9:20	Rückblick auf den letzten Workshop und Programm des heutigen Tages	Was ist das Ziel des gesamten Prozesses und wie wird das Ziel erreicht? Erläuterung und Begründung der Änderung des Programmablaufs. Vorstellung der kausale Gesamtnetze (Driver und Indikatoren) für die einzelnen Energiesparten.	Laptop und Beamer	MD
9:40	Abstimmung der kausalen Analystennetze im Plenum		Analoge kausale Analystennetze aus Karten und auf einem Flipchart	MD
10:20	Kaffeepause			Alle
10:30	Einführung in die normative Szenarien-Entwicklung			PD
10:40	Workshop 2	Erarbeitung der Story-		

	(Szenarien-Entwicklung)	lines zur Zielerreichung je Energiesparte mit verschiedenen Produktionszielen (Open Space)		
11:45	Zusammentragen der Ergebnisse	Wie können die Ziele in den einzelnen Energiesparten erreicht werden?	Pinnwand	Alle
12:15	Reflektion und Feedback	Was haben Sie heute Neues gelernt? Wie hat Ihnen die Methode der Szenarien-Entwicklung gefallen?	Reflektionskarte/Lernkarte	Alle
12:30	Ende der Veranstaltung	Wir wünschen Ihnen ein gutes Wochenende!		

Appendix E: Documentation of workshop 3

E-1: Informationen für die Stakeholder in Vorbereitung auf Workshop 3

Stellen Sie sich vor: Sie befinden sich im Jahr 2020.
30% des Stromverbrauchs im Kreis Groß-Gerau wird durch die Produktion von 350 Mio. kWh Regenerativstrom pro Jahr im Landkreis abgedeckt, verglichen mit nur 18 Mio. kWh im Jahr 2011.

Blicken Sie zurück auf die acht Jahre seit 2012:
Wie wurde, unter den gegebenen Rahmenbedingungen, dieser Ausbau der Regenerativstromerzeugung im Landkreis erreicht?

Im zweiten Workshop des partizipativen Prozesses haben wir begonnen die wichtigsten Einflussfaktoren zu identifizieren, auf die Sie als Akteure im Kreis Groß-Gerau keinen Einfluss nehmen können. Im Workshop hat die Zeit nicht gereicht, um diese Einflussfaktoren zu zwei Szenariorahmen (=Rahmenbedingungen) zu kombinieren. Dies hat die Arbeitsgruppe von Prof. Döll nachgeholt. Bitte nehmen Sie sich Zeit um die beiden von uns erstellten Szenariorahmen zu überprüfen und nachzuvollziehen. Sind die Welten, beschrieben durch die beiden Szenariorahmen, schlüssig und vorstellbar? Haben Sie Änderungswünsche?

Bitte bringen Sie Ihre Änderungswünsche zum kommenden Workshop, am 17.02.2012, mit. Wir werden dann gemeinsam die Entwicklung wichtiger Schlüsselfaktoren im Kreis Groß-Gerau unter den beschriebenen Bedingungen diskutieren und anschließend robuste Handlungen (Maßnahmen) aus den beiden Szenarien identifizieren. Weitere Informationen zum Vorgehen der Szenarienentwicklung können Sie bei Interesse den Folien des Vortrags von Prof. Döll aus dem letzten Workshop entnehmen.

Externe Einflussfaktoren

Die Einflussfaktoren lassen sich grob in drei Bereiche untergliedern. Dies sind:

- Finanzierungskonditionen
- Akzeptanz der Bürger
- Technologische Entwicklungen

Daneben ist die Entwicklung des Stromverbrauchs relevant. In den folgenden zwei Szenariorahmen sind unterschiedliche Entwicklungen dieser Einflussgrößen miteinander kombiniert.

Szenariorahmen 1: Finanzielle Hürden & Anstieg des Stromverbrauchs

Wir befinden uns im Jahr 2020. Die Rahmenbedingungen für den Ausbau der Regenerativstromerzeugung im Kreis Groß-Gerau haben sich seit dem Jahr 2012 wie folgt entwickelt:

- Die Wirtschaftskrise konnte überwunden werden, weswegen die Kreditzinsen auf inzwischen 10% gestiegen sind.
- Die Förderung der Regenerativstromerzeugung durch das EEG existiert nicht mehr; bereits 2014 wurde das sogenannte Mengenmodell eingeführt. Das Mengenmodell ist ein Quotenmodell, das Energieversorger verpflichtet, einen bestimmten Anteil ihres Stroms aus erneuerbaren Quellen zu liefern. Es ist den Energieversorgern selbst überlassen, aus welcher erneuerbaren Quelle der Strom kommt. Quotensysteme bedeuten eine Deckelung des Ausbaus erneuerbarer Energien auf einen vorgegebenen Maximalwert, zudem führen sie zu einer Monopolisierung des Ausbaus.
- Neben der Einführung des Mengenmodells hat das Land Hessen die Bürgschaft für die Bohrung für das erste tiefe Geothermiekraftwerk im Kreis Groß-Gerau nicht übernommen. Die Bohrungen fanden dennoch statt und lösten glücklicherweise kein Erdbeben aus. Auch sind in Deutschland bzw. Europa keine Erdbeben im Zusammenhang mit Bohrungen für neue tiefe Geothermiekraftwerke aufgetreten.
- Nachdem 2015 das Atomkraftwerk Grafenrheinfeld in Bayern abgeschaltet wurde, kam es in Deutschland zu einem Blackout. Es dauerte zwei Tage, bis die Stromversorgung wieder gesichert wurde.

- Die technische Entwicklung der Speichermedien ist stark vorangeschritten. Es stehen sowohl lokale Speichermedien für Haushalte als auch flächendeckende Lösungen, wie z.B. die Speicherung von Windgas im Untergrund, zur Verfügung.
- Die Höhe der nötigen Investitionen pro KWh-Strom im Bereich der Windenergie ist zurückgegangen, da geeignete Schwachwindanlagen entwickelt worden sind. Man kann davon sprechen, dass die Rentabilitätsschwelle überschritten ist. In der Energiesparte Photovoltaik hat die Effizienz der Anlagen nochmal stark zugenommen. Es werden durchschnittlich Wirkungsgrade von 40% erreicht.
- Der Stromverbrauch hat durch die technischen Entwicklungen wie Wärmepumpen, die Elektromobilität aber auch dem veränderten Lebensstil zugenommen (plus 10%).

Szenariorahmen 2: Technologischer Stillstand & Erdbeben in Hessen

Wir befinden uns im Jahr 2020. Die Rahmenbedingungen für den Ausbau der Regenerativstromerzeugung im Kreis Groß-Gerau haben sich seit dem Jahr 2012 wie folgt entwickelt:

- Die Kreditzinsen im Jahr 2020 sind seit 2012 nicht mehr gestiegen. Der Negativtrend der Zinsen hat sich fortgesetzt und sie liegen aktuell bei 2,1%.
- Die Einspeisevergütung für Strom aus den unterschiedlichen erneuerbaren Energieträgern ist seit 2012 wie geplant gesunken.
- Das Land Hessen hat 2014 die Bürgschaft für die erste Bohrung in der Energiesparte tiefe Geothermie übernommen. Nach der Niederbringung der ersten Bohrung ist ein Erdbeben der Stärke 6,7 in Hessen aufgetreten.
- Eine weitere atomare Katastrophe, hat die Welt erschüttert. Ein Verkehrflugzeug stürzte im Februar 2012 auf das AKW Forsmark in Schweden. Dadurch wurde die Ostküste Schwedens stark verseucht.
- Die Entwicklung der Speichermedien ist seit 2012 nicht weiter vorangetrieben worden. Es stehen keine rentablen Speichermedien zur Verfügung. Die Investitionen pro KWh-Strom im Bereich der Windenergie haben sich seit 2012 nicht geändert. Die Photovoltaikanlagen besitzen einen Wirkungsgrad von durchschnittlich 25%, ähnlich dem Wirkungsgrad von 2012.
- Der Stromverbrauch hat im Vergleich zum Jahr 2012 um 20% abgenommen.

Zusammenfassende Darstellung*

Einflussfaktor	Szenario Finanzielle Hürden & Anstieg des Stromverbrauchs	Szenario Technologischer Stillstand & Erdbeben in Hessen
Finanzierungskonditionen	-	+
Akzeptanz der Bevölkerung	-/+	-/+
Technologie	+	-
Stromverbrauch	-	+

* Die Plus- und Minuszeichen zeigen an, ob die Entwicklung der Einflussfaktoren die Zielerreichung fördert (+) oder hindert (-). Ein Minuszeichen bei Stromverbrauch bedeutet hier einen Anstieg des Stromverbrauchs, der die Erreichung der Abdeckung des Stromverbrauchs durch Regenerativstrom behindert.

E-2: Übersicht Planung Workshop 3

Tabelle E1: Planung Workshop 3.

Workshop 3 am Freitag, den 17.2.2012 – Szenarioentwicklung: Wie kann der Kreis Groß-Gerau das Ziel 30% Regenerativstromerzeugung im Jahr 2020 in den beiden Szenariorahmen erreichen?				
Ziele: Entwicklung von zwei Szenarien				
Zeit	Thema	Inhalt/Handlung	Materialien	Verantwortlich
9:00	Begrüßung der TN	Willkommen, Vorstellung des Workshopsteams, Programm des Tages	Flipchart mit Herzlich Willkommen und Zielen des Tages	PD, MD
9:10	Besprechung und Abstimmung Szenariorahmen (10 Minuten Vortrag Meike)	Sind die zwei Szenariorahmen für die Szenarien „Finanzielle Hürden & Anstieg des Stromverbrauchs“ und „Technologischer Stillstand & Erdbeben in Hessen“ vorstellbar?	Laptop und Beamer	MD
9:30	Entwicklung Szenarien Teil 1	1) Kurze Einführung in die Gruppenarbeit durch PD und MD (anhand ausformulierter Aufgabenstellung) für die Akteure (Was ist das Ziel?)2) [5´], Vorstellung des kausalen Netzes durch PD und MD mit Schlüsselfaktoren [5´] 3) Definition der Ausprägung der Schlüsselfaktoren [30´]; 4) Ergänzen von Handlungen, welche die Schlüsselfaktoren beeinflussen [10	Kausalen Netze mit Schlüsselfaktoren (weiße Karten) und Rahmenbedingungen (rosa Karten) an jeweils einer Pinnwand, weiße Karteikarten zur Ergänzung der Zustände der Schlüsselfaktoren, grüne Karten mit Handlungen (die bereits im Prozess identifiziert wurden und „Blankokarten“ für weitere Handlungen)	MD, PD, SF und TF
10:30	Kaffeepause			Alle
11:00	Entwicklung Szenarien Teil 2	´] 5) Durchdenken der Szenarien [20´]; 6) Präsentation der Ergebnisse im Plenum [20´]; 7) Auswahl der Handlungen [20´]	Pinnwand zum Sammeln der robusten Handlungen	MD, PD, SF und TF
12:00	Reflektion und Feedback	Welche neuen Erkenntnisse haben Sie gewonnen?	Reflektionskarte/Lernkarte)	Alle
12:15	Ausblick auf den kommenden Zusatzworkshop	Welche Ideen für konkrete Projekte im Bereich der Regenerativstromerzeugung existieren im Kreis Groß-Gerau?	Pinnwand und Moderationskarten	Alle
12:30	Ende			

E-3: Schritte der Szenarioentwicklung in Workshop 3

1) Bitte beschreiben Sie, wie sich die Rahmenbedingungen auf die Entwicklung der Schlüsselfaktoren ausgewirkt haben. Visualisieren Sie die Auswirkungen der Rahmenbedingungen (rosa Karten) auf die Schlüsselfaktoren (weiße Karten) durch das Einzeichnen der Verknüpfungen. Gleichzeitig notieren Sie bitte die Ausprägung der Faktoren in Stichworten auf den weißen Karten. Durch welche Ereignisse/Handlungen im Kreis Groß-Gerau wurde die Entwicklung wie beeinflusst? Bitte halten Sie diese Ereignisse/Handlungen auf den grünen Karten fest. [Dauer 50´]
2) Bitte durchdenken Sie das Szenario erneut und arbeiten die interessanten Aspekte des Szenarios heraus. [Dauer 20´]
3) Bitte stellen Sie (mit der Unterstützung der Moderatorin) Ihr Szenario anhand des kausalen Netzes im Plenum vor. [Dauer 10´ pro Gruppe]
4) Welche Handlungen/Ereignisse werden in beiden Szenarien genannt und zeichnen sich dadurch als robuste Handlungen aus? (Sammeln der Handlungen an der Pinnwand) [Dauer 20´]

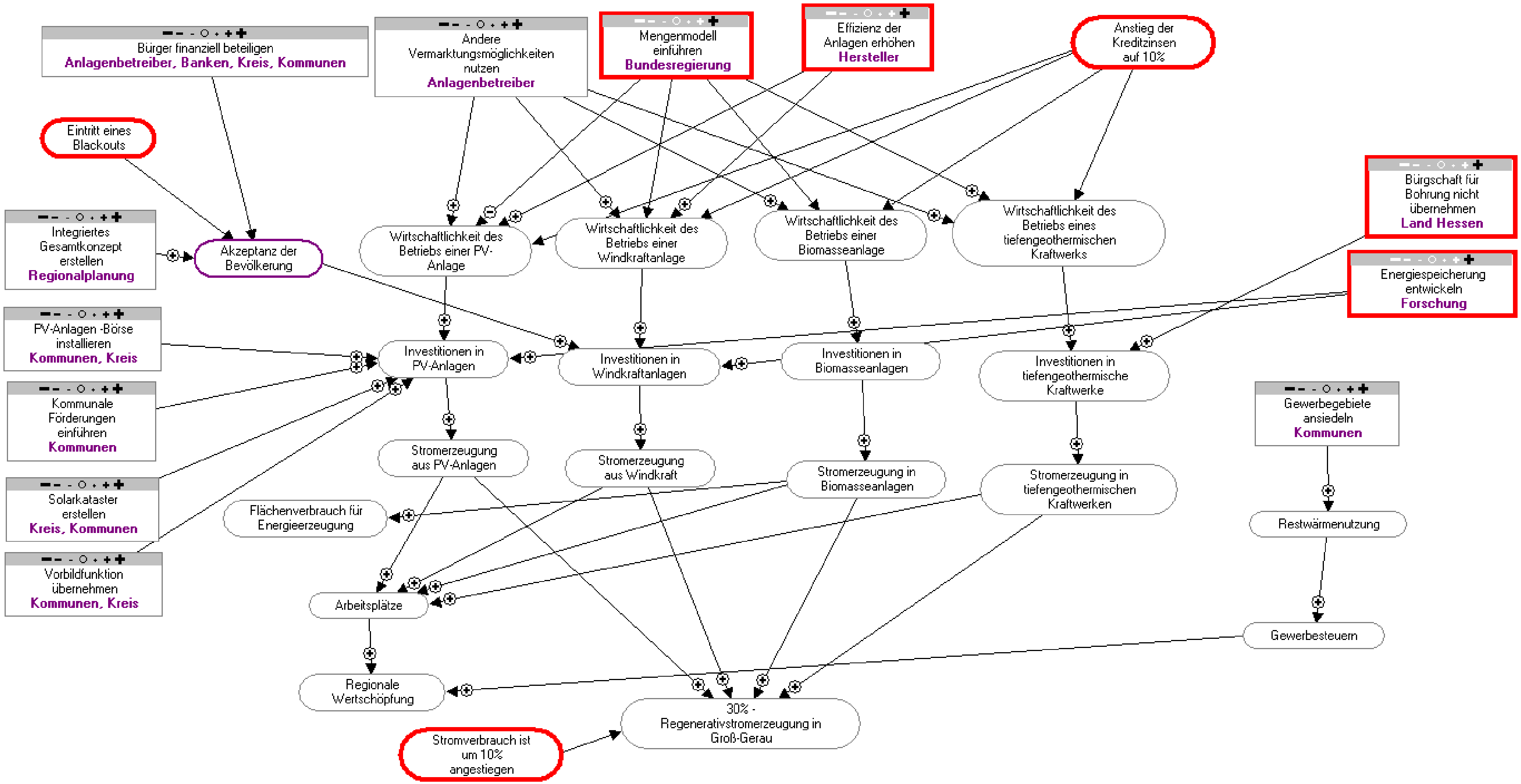


Abbildung E1: Kausales Netz für Szenario 1.

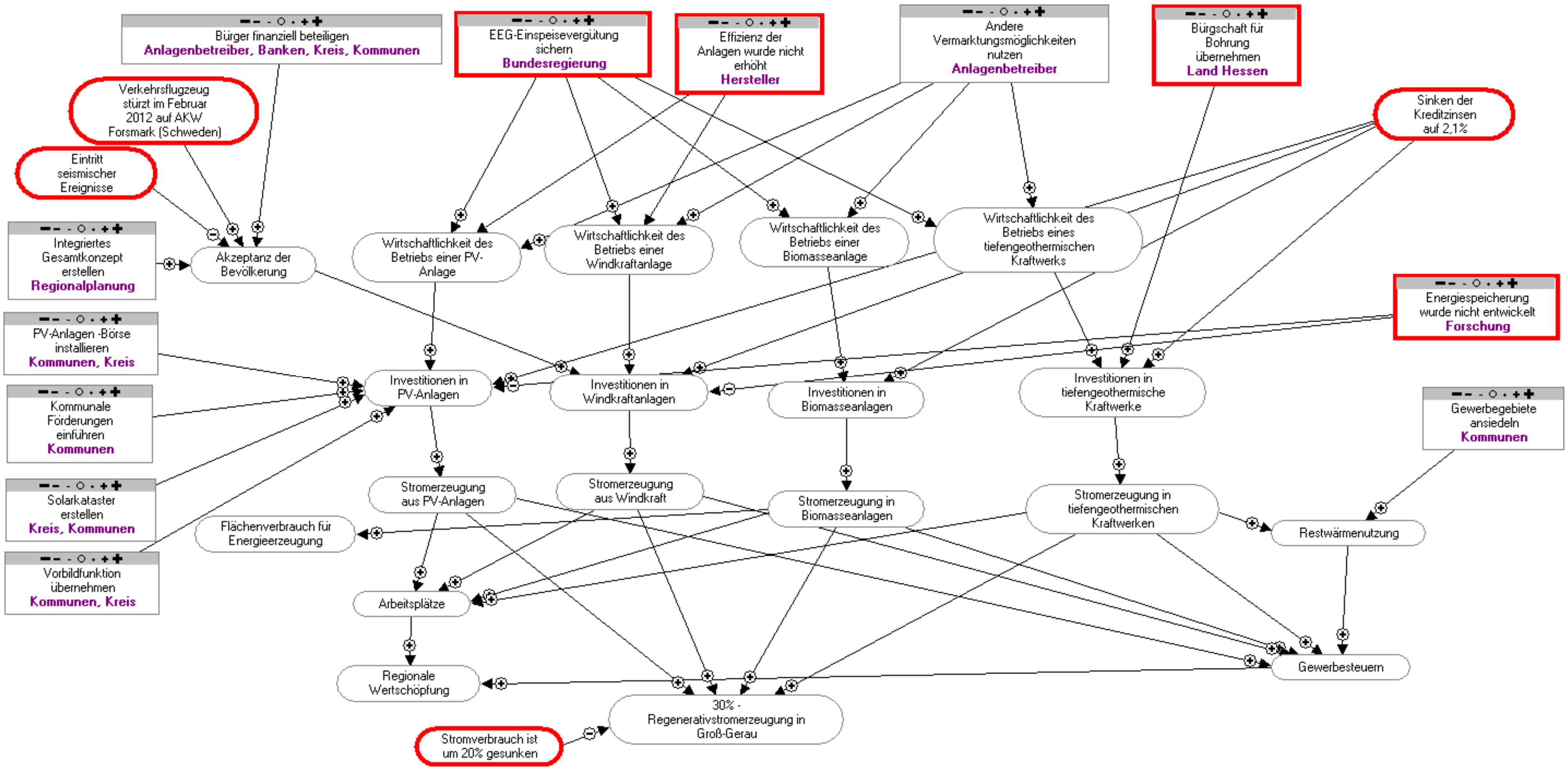


Abbildung E2: Kausales Netz für Szenario 2.

Appendix F: Documentation workshop 4

F-1: Planung Workshop 4 am 14.09.2012.

Tabelle F1: Planung Workshop 4.

Workshop 4 am Freitag den 14.09.2012 – Erarbeitung einer abgestimmten Strategie und Evaluation der Workshopreihe (eingesetzte Methoden, Ergebnis)				
Ziele: Erarbeitung abgestimmte Strategie für die Stromerzeugung aus erneuerbaren Energien Evaluation des partizipativen Prozesses hinsichtlich der eingesetzten Methoden und Ergebnisse				
Zeit	Thema	Inhalt/Handlung	Materialien	Verant-wortlich
9:00	Begrüßung der TN	Willkommen, Vorstellung des Workshopteams, Programm des Tages	Flipchart Willkommen und Zielen des Tages	PD, 1. KBO
9:10	Rückblick auf die letzten Workshops und Programm des heutigen Tages	Was ist das Ziel des gesamten Prozesses und wie wird das Ziel erreicht? Vorstellung der Ergebnisse der letzten Workshops: kausale Gesamtnetze (Driver und Indikatoren) für die einzelnen Energiesparten, 2 Szenarien, Vorgehen und Ziele des heutigen Tages (Aufhänger: „Wie treffen Sie Entscheidungen ohne BN?“).	Laptop und Beamer	MD
9:30	Einführung in die Bayes´schen Netze	Funktionsweise von Bayes´schen Netzen	Laptop und Beamer	MD
9:45	Analysen mit Bayes´schen Netzen	Darstellung der Auswirkungen verschiedener lokaler Handlungen und ihr Vergleich, paralleles Ausfüllen der Wahrscheinlichkeitstabellen für unterschiedliche Netze in unterschiedlichen Szenarien	Laptop und Beamer	MD, SF
10:30	Kaffeepause			Alle
10:45	Strategieentwicklung	„Das alles und noch viel mehr, würd ich machen, wenn ich König von Groß-Gerau wär“; 10 min Strategieentwicklung in Stillarbeit. Vorstellung und Diskussion der Strategien	Poster mit Handlungsoptionen; Anordnung entlang des Zeitstrahls	MD, AB

11:30	Auswahl der Strategien	Auswahl durch das Kleben von Punkten	Klebepunkte und Poster mit einzelnen Handlungsoptionen	
12:30	Kaffeepause			
12:45	Anschließende Schritte im PP	Erstellung einer Wunschliste durch TN.		MD, AB
13:30	Einführung in den Evaluationsbogen	Erläuterung der einzelnen Fragen im Evaluationsbogen		MD
13:35	Evaluation	Ausfüllen der Evaluationsbögen		Alle
14:00	Ende	Wir wünschen Ihnen ein gutes Wochenende!		

F-2: Fragebogen zur Evaluation des gesamten PSD, verteilt am letzten Workshop

Fragebogen zur Evaluation

Partizipative Entwicklung nachhaltiger und umsetzbarer Strategien für den Ausbau der Stromerzeugung aus erneuerbaren Energien im Kreis Groß-Gerau

September 2012

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Einführende Hinweise

*Auf den folgenden Seiten finden Sie Fragen zur Evaluation der partizipativen Strategieentwicklung für den Ausbau der Stromerzeugung aus erneuerbaren Energien im Kreis Groß-Gerau. Bitte nehmen Sie sich Zeit, den Fragebogen in Ruhe auszufüllen. Wir bitten Sie darum, ehrlich Ihre Meinung mitzuteilen, denn schließlich helfen Sie uns daduch, künftige Projekte zu verbessern. Wie Sie sehen werden, beziehen sich viele Fragen auf Ihre ganz persönliche Einschätzung. Daraus folgt: es gibt keine "richtigen" oder "falschen" Antworten - Ihre Einschätzung zählt! Der Fragebogen besteht aus verschiedenen Teilen. In dem ersten **Teil A** werden Ihnen Fragen zur Ihrer Teilnahme am partizipativen Prozess gestellt. **Teil B** beschäftigt sich mit der Evaluation des partizipativen Prozesses allgemein und im anschließenden **Teil C** werden die eingesetzten Methoden beleuchtet. Im **Teil D** werden die Ergebnisse des partizipativen Prozesses von Ihnen bewertet.*

Falls Sie Fragen kommentieren oder bei bestimmten Fragen ausführlichere Antworten geben wollen, können Sie dies auf der letzten Seite des Fragebogens gerne tun.

Teil A - Ihre Teilnahme am partizipativen Prozess

1 **An welchen Workshops bzw. Veranstaltungen im Rahmen des partizipativen Prozesses haben Sie teilgenommen? (Mehrere Antwortmöglichkeiten)**

- [ ] Auftaktveranstaltung - Dez. 2011
- [ ] Interview (kausales Netz)
- [ ] 1. Workshop (Einführung) - Dez. 2011
- [ ] 2. Workshop (Gesamtnetze) - Jan. 2012
- [ ] 3. Workshop (Szenarien) - Feb. 2012
- [ ] 4. Workshop ("Zusatzworkshop") - März 2012
- [ ] Netzwerk Energie-Treffen (Zwischenstand) - Juni 2012
- [ ] 5. Workshop (Strategieentwicklung) - Sept. 2012

A2 **Welche dieser Veranstaltungen war Ihrer Meinung nach die wichtigste? Warum?**

____

____

____

A3 **Was war Ihre Motivation an dem partizipativen Prozess teilzunehmen? Bitte kreuzen Sie an:**

- [ ] ein bestimmtes Problem einbringen
- [ ] über die Stromversorgung im Kreis GG lernen
- [ ] regionale Situation der Stromerzeugung aus EE verbessern
- [ ] Perspektiven anderer Teilnehmer auf die Stromversorgung kennenlernen
- [ ] eigene Vorhaben im partizipativen Prozess voranbringen
- [ ] Wissen und Informationen einbringen
- [ ] mögliche Zukunftsszenarien entdecken
- [ ] bestimmte Interessen verteidigen und schützen
- [ ] Netzwerke mit anderen Teilnehmern aufbauen/stärken
- [ ] andere Motivation: ______________________________

Teil B - Der partizipative Prozess

B1 **Welche der folgenden Interessensgruppen waren im partizipativen Prozess nicht ausreichend, ausreichend oder zu stark vertreten?**

	Nicht ausreichend vertreten	Ausreichend vertreten	Zu stark vertreten
Netzbetreiber	☐	☐	☐
Kommune	☐	☐	☐
Naturschutzverbände	☐	☐	☐
Kreisverwaltung	☐	☐	☐
Energieversorger	☐	☐	☐
Landwirtschaft	☐	☐	☐
Wissenschaft	☐	☐	☐
Banken	☐	☐	☐
Handswerkskammer	☐	☐	☐
Industrie- u. Handelskammer	☐	☐	☐

B2 **Gibt es Interessensgruppen, die Ihrer Meinung nach am Prozess hätten teilnehmen sollen, aber nicht vertreten waren? Wenn ja, welche Interessensgruppe(n) ist (sind) dies?**

____

____

B3 **Haben Sie während des partizipativen Prozesses Spannungen unter den Teilnehmern bemerkt, die den Prozess negativ beeinflusst haben? Wenn ja, welcher Art waren diese Spannungen?**

____

____

____

B4 **Am partizipativen Prozess sind verschiedene Institutionen mit unterschiedlichen Aufgaben beteiligt. Kreuzen Sie bitte an, inwieweit die Aufgaben in Ihren Augen erfüllt wurden.**

		gar nicht erfüllt	**eher nicht erfüllt**	**teilweise erfüllt**	**eher erfüllt**	**voll-kommen erfüllt**	**k. A.**
EKC	Organisation der Workshops	☐	☐	☐	☐	☐	☐
	Bereitstellen von Informationen	☐	☐	☐	☐	☐	☐
	Führungsrolle	☐	☐	☐	☐	☐	☐
Uni Frankfurt	Durchführung der Interviews	☐	☐	☐	☐	☐	☐
	Einführung in die verwendeten Methoden	☐	☐	☐	☐	☐	☐
	Moderation der Workshops	☐	☐	☐	☐	☐	☐
	Analyse von Daten und Informationen	☐	☐	☐	☐	☐	☐
	Dokumentation der Workshopergebnisse	☐	☐	☐	☐	☐	☐
Alle	Vertretung der Interessen der Teilnehmer	☐	☐	☐	☐	☐	☐
	weitere:						

Teil C - Methoden im partizipativen Prozess

Im Rahmen des partizipativen Prozesses kamen verschiedene Methoden zum Einsatz, die die gemeinsame Strategieentwicklung unterstützten. Die Methoden waren die folgenden:

Anwendungszeitpunkt	Methode
Interview vor dem 1. Workshop	Erstellung eines akteursspezifischen kausalen Netzes
1. Workshop	Nutzung der kausalen Netze zur Vorstellung
2. Workshop	Erarbeitung von energiespartenspezifischen kausalen Gesamtnetzen
3. Workshop	Entwicklung von zwei Szenarien zur Regenerativstromerzeugung im Jahr 2020
4. Workshop	energiespartenspezifische Bayes´sche Netze

C1 **Bitte bewerten Sie die folgenden Aussagen bezüglich der Erstellung und Nutzung der akteursspezifischen kausalen Netze im partizipativen Prozess, indem Sie entsprechende Kreuzchen setzen.**

Die Konstruktion und die Anwendung der akteursspezifischen kausalen Netze :	**trifft überhaupt nicht zu**	**trifft eher nicht zu**	**trifft teilweise zu**	**trifft eher zu**	**trifft vollkommen zu**	**k.A.**
hat meiner Organisation geholfen unsere institutionelle Perspektive intern zu reflektieren .	☐	☐	☐	☐	☐	☐
hat den anderen Akteuren unsere institutionelle Perspektive verdeutlicht.	☐	☐	☐	☐	☐	☐
hat die Perspektiven der anderen Interessensgruppen für mich transparent gemacht.	☐	☐	☐	☐	☐	☐
war für mich nachvollziehbar und verständlich.	☐	☐	☐	☐	☐	☐

C2 **Bitte bewerten Sie die folgenden Aussagen bezüglich der Erstellung und Nutzung der energiespartenspezifischen kausalen Gesamtnetze im partizipativen Prozess, indem Sie entsprechende Kreuzchen setzen.**

Die Konstruktion und die Anwendung der Gesamtnetze :	**trifft überhaupt nicht zu**	**trifft eher nicht zu**	**trifft teilweise zu**	**trifft eher zu**	**trifft vollkommen zu**	**k. A.**
hat das Wissen der anwesenden Interessensgruppen zusammengebracht.	☐	☐	☐	☐	☐	☐
hat wichtige Zusammenhänge der Regenerativstromversorgung im Kreis GG verdeutlicht.	☐	☐	☐	☐	☐	☐
hat Handlungsmöglichkeiten der Akteure aufgezeigt.	☐	☐	☐	☐	☐	☐
hat den anderen Akteuren unsere institutionelle Perspektive veranschaulicht.	☐	☐	☐	☐	☐	☐
hat die Perspektiven der anderen Organisationen für mich transparent gemacht.	☐	☐	☐	☐	☐	☐
war für mich nachvollziehbar und verständlich.	☐	☐	☐	☐	☐	☐

C3 **Inwieweit stimmen Sie mit der Aussage überein, dass für eine erfolgreiche Entwicklung von Handlungsstrategien externe Einflussfaktoren (z.B. Förderung der EE) berücksichtig werden sollten.**

trifft überhaupt nicht zu	**trifft eher nicht zu**	**trifft teilweise zu**	**trifft eher zu**	**trifft vollkommen zu**	**k. A.**
☐	☐	☐	☐	☐	☐

C4 **Bitte bewerten Sie die folgenden Aussagen bezüglich der Entwicklung von zwei Szenarien**

zur Regenerativstromerzeugung im Jahr 2020 für den Kreis Groß-Gerau, indem Sie entsprechende Kreuzchen setzen.

Die Entwicklung von zwei Szenarien:	**trifft überhaupt nicht zu**	**trifft eher nicht zu**	**trifft teilweise zu**	**trifft eher zu**	**trifft vollkommen zu**	**k. A.**
hat zum besseren Verständnis ext. Einflussesfaktoren und deren unsicherer Entwicklung geführt	☐	☐	☐	☐	☐	☐
hat langfristig robuste Handlungsmöglichkeiten der Akteure aufgezeigt.	☐	☐	☐	☐	☐	☐
hat die Perspektiven der anderen Interessensgruppen für mich transparent gemacht.	☐	☐	☐	☐	☐	☐
war für mich nachvollziehbar und verständlich.	☐	☐	☐	☐	☐	☐

C5 **Bitte bewerten Sie die folgenden Aussagen bezüglich der Erstellung und Nutzung der energiespartenspezifische Bayes´schen Netze im partizipativen Prozess, indem Sie entsprechende Kreuzchen setzen.**

Die Konstruktion und die Anwendung der Bayes´schen Netze:	**trifft überhaupt nicht zu**	**trifft eher nicht zu**	**trifft teilweise zu**	**trifft eher zu**	**trifft vollkommen zu**	**k. A.**
hat Wissenslücken oder ein Defizit an Informationen identifiziert.	☐	☐	☐	☐	☐	☐
hat wichtige Zusammenhänge der Regenerativstromversorgung im Kreis GG verdeutlicht.	☐	☐	☐	☐	☐	☐
hat Handlungsmöglichkeiten der Akteure aufgezeigt.	☐	☐	☐	☐	☐	☐
hat die Auswahl an Handlungsmöglichkeiten unterstützt.	☐	☐	☐	☐	☐	☐
hat Ergebnisse in einem nützlichen Format						

(Wahr-scheinlichkeitsverteilungen) erzeugt.	☐	☐	☐	☐	☐	☐
war für mich nachvollziehbar und verständlich.	☐	☐	☐	☐	☐	☐

C6 **Vergleichen Sie bitte eine partizipative Strategieentwicklung mittels Brainstorming, Diskussion in Kleingruppen und im Plenum mit unserer partizipativen Strategieentwicklung unter Verwendung der genannten Methoden.**

Die verwendeten Methoden:	**trifft überhaupt nicht zu**	**trifft eher nicht zu**	**trifft teilweise zu**	**trifft eher zu**	**trifft vollkommen zu**	**k. A.**
haben die Diskussionen inhaltlich besser strukturiert und effizienter gestaltet.	☐	☐	☐	☐	☐	☐
haben stärker animiert, Informationen und Sichtweisen auszutauschen und einzubringen.	☐	☐	☐	☐	☐	☐
haben die Perspektiven aller Teilnehmer besser berücksichtigt.	☐	☐	☐	☐	☐	☐
haben zu einem höheren Wissenszuwachs bei den einzelnen Teilnehmern geführt.	☐	☐	☐	☐	☐	☐

Teil D - Ergebnisse des partizipativen Prozesses

D1 **Was sind für Sie die wichtigsten Ergebnisse des partizipativen Prozesses?**

☐ Wissen (Systemverständnis, mögliche Handlungsansätze, etc.)

☐ weiterführende Events/Arbeitstreffen

☐ Neue oder intensivierte Kontakte zu anderen Teilnehmern

☐ Dokumentation des partizipativen Prozesses und seiner Ergebnisse

☐ Weitere: ______________________

____

☐ Strategien zum Ausbau der Regenerativstromerzeugung

D2 Bitte bewerten Sie die im partizipativen Prozess entwickelten Strategien:

Die entwickelten Strategien:	**trifft überhaupt nicht zu**	**trifft eher nicht zu**	**trifft teil-weise zu**	**trifft eher zu**	**trifft voll-kommen zu**	**k.A.**
sind in sich stimmig.	☐	☐	☐	☐	☐	☐
sind konkret und umsetzbar.	☐	☐	☐	☐	☐	☐
sind in meinem Sinne.	☐	☐	☐	☐	☐	☐

D3 Bitte kreuzen Sie an:

Meine Teilnahme am partizipativen Prozess:	**trifft überhaupt nicht zu**	**trifft eher nicht zu**	**trifft teil-weise zu**	**trifft eher zu**	**trifft voll-kommen zu**	**k. A.**
hat mein Verständnis für die Anliegen der anderen Teilnehmer vergrößert.	☐	☐	☐	☐	☐	☐
hat meine Bereitschaft, Informationen mit anderen Teilnehmern zu teilen, erhöht.	☐	☐	☐	☐	☐	☐
hat mein Vertrauen in mögliche zukünftige gemeinsame Projekte gestärkt.	☐	☐	☐	☐	☐	☐
hat meine Motivation gesteigert, mich für die Regenerativstrom-versorgung einzusetzen.	☐	☐	☐	☐	☐	☐
hat einen angemessenen Zeitaufwand hinsichtlich der Ergebnisse beansprucht.	☐	☐	☐	☐	☐	☐

D4 Kreuzen Sie bitte an.

Während des partizipativen Prozesses:

☐ habe ich neue Kontakte geknüpft ☐ habe ich bestehende Kontakte intensiviert

D5 Inwieweit fühlen Sie sich für die gemeinsam erarbeiteten Ergebnisse verantwortlich?

trifft überhaupt nicht zu	trifft eher nicht zu	trifft teilweise zu	trifft eher zu	trifft vollkommen zu	k.A.
☐	☐	☐	☐	☐	

D6 Begründen Sie bitte hier kurz Ihre Antwort zu D5.

____

____

D7 Würden Sie noch einmal an einem partizipativen Prozess teilnehmen?

☐ ja ☐ nein ☐ vielleicht

Appendix G: Documentation of completed PSD

Partizipative Entwicklung nachhaltiger und umsetzbarer Strategien für den Ausbau der Stromerzeugung aus erneuerbaren Energien im Kreis Groß-Gerau

Dokumentation des partizipativen Prozesses

März 2013

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Zusammenfassung

Der Kreis Groß-Gerau hat sich ambitioniert das Ziel gesetzt, bis 2020 den Anteil des Regenerativstroms an der Stromversorgung auf 30% zu erhöhen. Das Potenzial zur Deckung des gesamten Stromverbrauchs aus Regenerativstrom ist vorhanden. Der Stromverbrauch von ca. einer Mio. kWh kann durch die Energiesparten tiefe Geothermie, Photovoltaik, Windenergie und Biomasse gedeckt werden. Um das Ziel zu erreichen, braucht der Kreis umsetzbare Strategien. Das Energiekompetenzcenter des Kreises lud Akteure aus dem Kreis Groß-Gerau ein, nachhaltige und umsetzbare Strategien zum Ausbau der Stromerzeugung im Kreis Groß-Gerau in einem partizipativen Prozess zu erarbeiten. Der partizipative Prozess dauerte ein gutes Jahr (Dezember 2011 bis November 2012). In den vier Workshops des partizipativen Prozesses kamen verschiedene Methoden zum Einsatz, mit denen Netzwerkbildung unter den Akteuren, Wissensintegration aller Akteure und am Ende die Strategieentwicklung gefördert werden sollte.

Der Einsatz der akteursspezifischen kausalen Netze zeigt, dass alle teilnehmenden Akteure das Ziel verfolgen, den Anteil der erneuerbaren Energien an der Stromversorgung und damit auch die regionale Wertschöpfung zu erhöhen, jedoch unterschiedliche Handlungsmöglichkeiten sehen. Die kausalen Gesamtnetze tragen diese Handlungsmöglichkeiten für die einzelnen Energiesparten zusammen. Die Szenarioanalyse zeigt, dass externe, unsichere Faktoren wie z.B. die Förderung der Einspeisung von Regenerativstrom durch das EEG, einen großen Einfluss auf die Zielerreichung durch den Kreis haben. Je nach Entwicklung der externen Faktoren muss entweder die Zielsetzung angepasst werden oder Handlungen in den einzelnen Energiesparten verstärkt werden. Die Erkenntnisse der Szenarioanalyse wurden in den kausalen Gesamtnetzen aufgegriffen und die Auswirkungen verschiedener Handlungen auf die Zielerreichung mit Hilfe von (bedingten) Wahrscheinlichkeiten in den Bayes´sche Netzen quantifiziert. Durch die Akteure wurden im letzten Schritt Handlungsoptionen in den Energiesparten tiefe Geothermie, Photovoltaik und Windenergie ausgewählt, die die höchste Effektivität besitzen. Neben diesen Handlungsoptionen sahen die Akteure Handlungen in den Bereichen Energieeinsparung und integrative Versorgungssysteme (KWK) als sehr wichtig an.

Die Organisation und Durchführung des partizipativen Prozesses wurden durch die Akteure evaluiert. Laut der Evaluation hätten sich die Akteure seine stärkere Präsenz der verschiedenen Kommunen im Landkreis und der Landwirtschaft sowie energiespezifische Expertise aus der Wissenschaft gewünscht. Die Motivation der teilnehmenden Akteure lag hauptsächlich darin, das Netzwerk mit den anderen Akteuren

zu stärken bzw. aufzubauen und die Perspektiven der anderen Akteure auf die Energieversorgung im Kreis Groß-Gerau kennenzulernen. Die im Prozess eingesetzten Methoden wurden u.a. hinsichtlich der Verdeutlichung von Zusammenhängen, der Entwicklung von Handlungsoptionen und des Austauschs von Perspektiven der Akteure im Durchschnitt positiv bewertet.

Der partizipative Prozess

Der Kreis Groß-Gerau hat sich durch den Beitritt zum Klimaschutzbündnis das Ziel gesetzt, die CO_2-Emissionen pro Kopf und Jahr bis 2030 gegenüber 1990 um 50% zu reduzieren. Ein Schritt zur Zielerreichung ist der Ausbau des Anteils der Regenerativstromerzeugung an der Stromerzeugung des Kreises auf 30% im Jahre 2020. Langfristig wird eine vollständige Versorgung aus erneuerbaren Energien angestrebt. Die Potenziale für die Stromversorgung aus erneuerbaren Energien (Tabelle G) sind vorhanden.

Tabelle G1: Potenziale der Stromerzeugung aus erneuerbaren Energien (Quelle: TU Darmstadt und juwi Holding AG [26])

	Stromverbrauch 2007: 1.246 Mio. kWh (ohne Opel)
	potenziell mögliche Stromerzeugung
Energieträger	**GWh/a**
Biomasse (gasförmig)	27
Photovoltaik (Dachflächen)	368
Photovoltaik (Freiflächen)	106 (Fläche 368 ha)
Tiefe Geothermie	510
Windenergie	175 (Fläche 900 ha, 30 Anlagen je 2,5 MW)
Gesamt	1186

Relevante Akteure im Kreis Groß-Gerau, federführend das Energiekompetenzcenter des Kreises, entwickelten gemeinsam mit der Universität Frankfurt (Prof. Dr. Petra Döll und Meike Düspohl) partizipativ Strategien für den Ausbau der Stromerzeugung aus erneuerbaren Energien. Der partizipative Prozess startete im Dezember 2011 mit einer Auftaktveranstaltung und endete im November 2012 mit einem Abschlussworkshop. Insgesamt fanden zwischen diesen beiden Veranstaltungen im Rahmen des Prozesses drei weitere Workshops statt. An dem Prozess nahmen Akteure aus Politik, Wirtschaft und Wissenschaft teil. Ziel des Prozesses war es zum einen, umsetzbare Strategien zum Ausbau der erneuerbaren Energien für den Kreis Groß-Gerau zu entwickeln. Neben der Strategieentwicklung sollten die beteiligten

Akteure ihr Wissen über die einzelnen Energiesparten bzw. über allgemeine Entwicklungen im Bereich der Regenerativstromerzeugung vertiefen. Ein weiterer Fokus im Prozess wurde auf das Kennenlernen der Perspektiven der anderen beteiligten Akteure gelegt und damit auch eine Vernetzung der Akteure gefördert. Der Ablauf des partizipativen Prozesses sah im ersten Schritt die Erhebung der Perspektiven der einzelnen Akteure auf die Stromversorgung aus erneuerbaren Energien im Kreis Groß-Gerau vor. Dazu wurden akteursspezifische kausale Netze in einem Interview erstellt und ausgetauscht. Die kausalen Netze enthalten jeweils das Ziel (die Erhöhung des Anteils erneuerbarer Energien an der Stromversorgung), Faktoren die dieses Ziel bedingen und Handlungen, die auf die Faktoren einwirken. Die unterschiedlichen Faktoren wurden in energiespartenspezifischen kausalen Gesamtnetzen integriert und damit das System der Regenerativstromerzeugung im Kreis Groß-Gerau erfasst. Im zweiten und dritten Workshop wurde das Verhalten des Systems unter verschiedenen Rahmenbedingungen in einer Szenarioanalyse betrachtet und Handlungen unter den veränderten Bedingungen beschrieben, die eine Zielerreichung zulassen. Die Erkenntnisse aus der Szenarioanalyse wurden im vierten Workshop in den kausalen Gesamtnetzen aufgegriffen; es wurden die Auswirkungen von verschiedenen Handlungen auf die Zielerreichung stochastisch (Bayes´sche Netze) quantifiziert und darauf basierend effektive Handlungen durch die teilnehmenden Akteure ausgewählt.

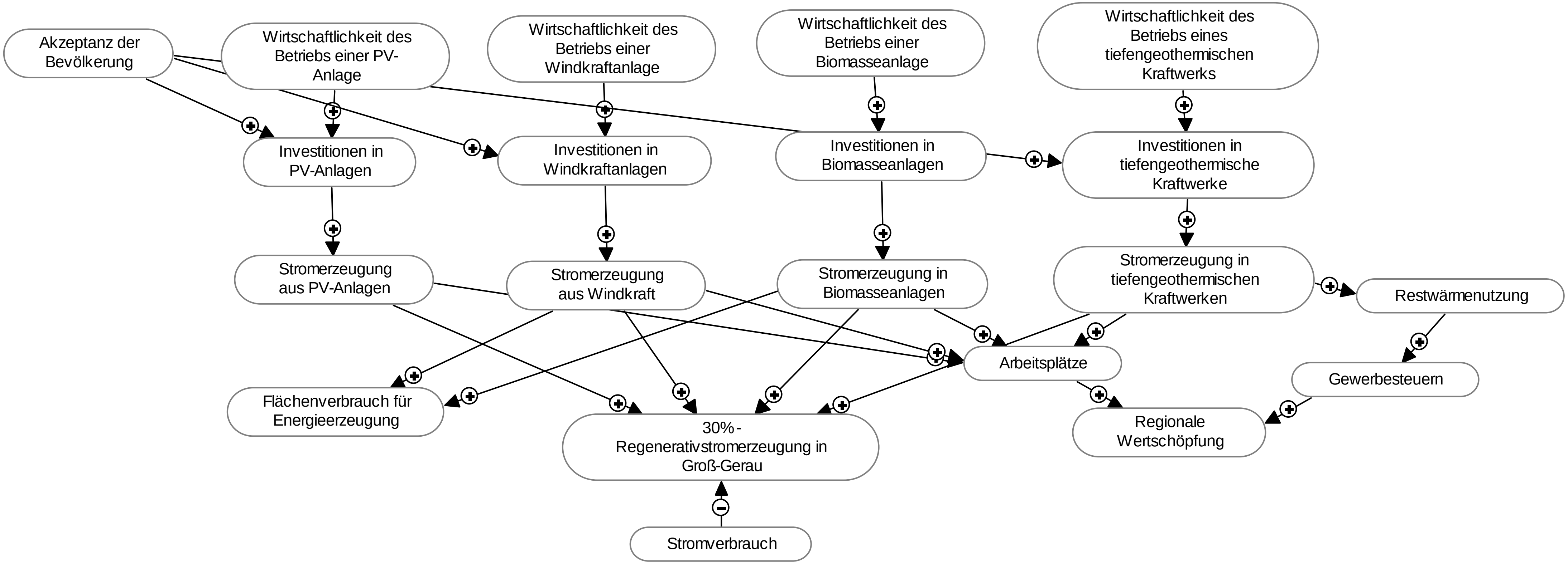
2 Ergebnisse des partizipativen Prozesses

Die Ergebnisse der einzelnen Workshops wurden den Teilnehmern jeweils nach den Workshops zur Verfügung gestellt. Auf den folgenden Seiten finden sich sowohl die Ergebnisse des Abschlussworkshops (entwickelte Handlungsoptionen, Bayes´sche Netze) als auch wichtige Ergebnisse des gesamten Prozesses (kausales Gesamtnetz, Szenarioanalyse, akteursspezifische kausale Netze). Die Darstellung der Ergebnisse erfolgt dem Prozessverlauf entsprechend und beginnt mit der Darstellung des kausalen Gesamtnetzes als Ausgangssystem für die Entwicklung von Handlungsoptionen.

2.1 Kausales Gesamtnetz

Das kausale Gesamtnetz (Abbildung G1) umfasst Faktoren der vier Energiesparten. Das Netz ist Ergebnis des ersten Workshops und beschreibt vereinfacht das System der Regenerativstromerzeugung im Landkreis. Es macht deutlich, dass die Zielerreichung im Kreis Groß-Gerau stark von der Wirtschaftlichkeit der Stromerzeugung in den einzelnen Energiesparten abhängt. Weitere wichtige Faktoren sind die Akzeptanz der Bevölkerung, die in den einzelnen Energiesparten eine unterschiedliche Bedeutung einnimmt. In der Energiesparte der Photovoltaik führt eine hohe Akzeptanz der Bevölkerung zu Investitionen der Verbraucher selbst. Bei der Windkraft, der Biomasse und der tiefen Geothermie ist die Akzeptanz der Bevölkerung Kriterium für den Bau von Anlagen im Kreis. Neben dem Ziel, die Regenerativstromerzeugung auf 30% zu steigern, ist im Kreis die regionale Wertschöpfung und der Flächenverbrauch für die Energieerzeugung relevant. Der Stromverbrauch im Kreis spielt bei der Zielerreichung eine wichtige Rolle. Je niedriger der Stromverbrauch, desto höher kann der Anteil an erneuerbaren Energien an der Stromerzeugung werden. Der Flächenverbrauch für die Energieerzeugung, als ein ökologischer Aspekt, soll möglichst gering gehalten werden.

Das kausale Gesamtnetz bietet die Möglichkeit, vereinfacht das System der Regenerativstromerzeugung im Kreis Groß-Gerau darzustellen und kann als Diskussionsgrundlage für den Austausch über das System dienen. Das in Abbildung gezeigte Netz ist nicht vollständig, da Handlungen und externe Faktoren, die auf das System wirken, nicht enthalten sind. Diese werden in der Szenarioanalyse im nächsten Absatz näher betrachtet.



AbbildungG1: Vereinfachtes kausales Gesamtnetz der vier Energiesparten Photovoltaik, Windkraft, Biomasse und tiefe Geothermie zur Beschreibung des Systems der Regenerativstromerzeugung im Landkreis Groß-Gerau.

2.2 Szenarioanalyse

Während des zweiten und dritten Workshops wurden zwei verschiedene Szenarien entwickelt. Szenarien sind „Wenn …, dann …“-Geschichten über alternative Zukünfte. Sie beschreiben eine Abfolge von Ereignissen unter Berücksichtigung der wichtigsten Systemzusammenhänge. Dabei sollten die Szenarien plausibel, konsistent und interessant bzw. lehrreich sein. Szenarien sind keine Vorhersagen und sollten daher nicht mit Wahrscheinlichkeiten belegt werden. Szenarien der Zukunft unterstützen Entscheidungen heute. Insbesondere unterstützen sie die folgende Art von Entscheidungen:

- Entscheidungen in Feldern, deren zukünftige Entwicklung unsicher ist und deren Entwicklung nicht vollständig vom Entscheidungsträger beeinflusst werden kann
- Entscheidungen, die sich langfristig als gut erweisen sollen
- Entscheidungen, die robust sein sollen, d.h. in unterschiedlichen Zukünften sich als gut erweisen.

Aufgabenstellung für die Akteure zur Szenarioanalyse:

> Stellen Sie sich vor, dass Sie sich im Jahr 2020 befinden. 30% des Stromverbrauchs im Kreis Groß-Gerau wird durch die Produktion von 350 Millionen kWh Regenerativstrom pro Jahr im Landkreis abgedeckt, verglichen mit nur 18 Millionen kWh im Jahr 2011. Wie wurde, unter den gegebenen Rahmenbedingungen, dieser Ausbau der Regenerativstromerzeugung im Landkreis erreicht?

Das Ergebnis der Szenarioanalyse sind zwei verschiedene Szenarien, die sich in den externen Einflussfaktoren (Szenarienrahmen) unterscheiden. Die wichtigsten externen Einflussfaktoren der Regenerativstromerzeugung wurden in Workshop 2 durch die Akteure identifiziert und durch das Team der Goethe Universität Frankfurt zu zwei Szenarienrahmen kombiniert. Die beiden Szenarien der zukünftigen Regenerativstromentwicklung in Groß-Gerau, unter den beiden Szenarienrahmen, wurden in Workshop 3 durch die Akteure erarbeitet.

2.2.1 Szenarien(rahmen) 1: Finanzielle Hürden & Anstieg des Stromverbrauchs

Wir befinden uns im Jahr 2020. Die Rahmenbedingungen für den Ausbau der Regenerativstromerzeugung im Kreis Groß-Gerau haben sich seit dem Jahr 2012 wie folgt entwickelt:

- Die Förderung der Regenerativstromerzeugung durch das EEG existiert nicht mehr; bereits 2014 wurde das sogenannte Mengenmodell eingeführt. Das Mengenmodell ist ein Quotenmodell, das Energieversorger verpflichtet, einen bestimmten Anteil ihres Stroms aus erneuerbaren Quellen zu liefern. Es ist den Energieversorgern selbst überlassen, aus welcher erneuerbaren Quelle der Strom kommt. Quotensysteme bedeuten eine Deckelung des Ausbaus erneuerbarer Energien auf einen vorgegebenen Maximalwert, zudem führen sie zu einer Monopolisierung des Ausbaus.
- Die Wirtschaftskrise konnte überwunden werden, weswegen die Kreditzinsen auf inzwischen 10% gestiegen sind.
- Neben der Einführung des Mengenmodells hat das Land Hessen die Bürgschaft für die Bohrung für das erste tiefe Geothermiekraftwerk im Kreis Groß-Gerau nicht übernommen. Die Bohrungen fanden dennoch statt und lösten glücklicherweise kein Erdbeben aus. Auch sind in Deutschland bzw. Europa keine Erdbeben im Zusammenhang mit Bohrungen für neue tiefe Geothermiekraftwerke aufgetreten.
- Nachdem 2015 das Atomkraftwerk Grafenrheinfeld in Bayern abgeschaltet wurde, kam es in Deutschland zu einem Blackout. Es dauerte einen Tag, bis die Stromversorgung wieder gesichert wurde.
- Die technische Entwicklung der Speichermedien ist stark vorangeschritten. Es stehen sowohl lokale Speichermedien für Haushalte als auch flächendeckende Lösungen, wie z.B. die Speicherung von Windgas im Untergrund, zur Verfügung.
- Die Höhe der nötigen Investitionen pro KWh-Strom im Bereich der Windenergie ist zurückgegangen, da geeignete Schwachwindanlagen entwickelt worden sind. Man kann davon sprechen, dass die Rentabilitätsschwelle überschritten ist. In der Energiesparte Photovoltaik hat die Effizienz der Anlagen nochmal stark zu genommen. Es werden durchschnittlich Wirkungsgrade von 40% erreicht.
- Der Stromverbrauch hat durch die technischen Entwicklungen wie Wärmepumpen, die Elektromobilität aber auch dem veränderten Lebensstil zugenommen (plus 10%)
- Der Strompreis ist in den letzten acht Jahren moderat angestiegen.
- Der Ölpreis ist stark angestiegen.

Ziel in diesem Szenario ist eine Regenerativstromerzeugung in Höhe von 412,5 Mio kWh_{el}. Dies entspricht 30% des Stromverbrauchs in Groß-Gerau im Jahre 2020. Das Szenario gestaltet sich wie folgt:

Tabelle G2: Zusammenfassende Darstellung der Regenerativstromproduktion im Jahr 2020 unter den Rahmenbedingungen des Szenario 1.

Energiesparte	Regenerativstromerzeugung (in Mio. kWh_{el} pro Jahr)	Prozentualer Anteil an Stromerzeugung (in%)
Photovoltaik	?	?
Tiefe Geothermie	20 - 25	1,6 - 1,8
Biomasse	16	1,2
Windkraft	0	0
Gesamt	36 - 41	2,8 - 3

2.2.2 Szenarien(rahmen) 2: Technologischer Stillstand & Erdbeben in Hessen

Wir befinden uns im Jahr 2020. Die Rahmenbedingungen für den Ausbau der Regenerativstromerzeugung im Kreis Groß-Gerau haben sich seit dem Jahr 2012 wie folgt entwickelt:

- Die Kreditzinsen im Jahr 2020 sind seit 2012 nicht mehr gestiegen. Der Negativtrend der Zinsen hat sich fortgesetzt und sie liegen aktuell bei 2,1 %.
- Die Einspeisevergütung für Strom aus den unterschiedlichen erneuerbaren Energieträgern ist seit 2012 wie geplant gesunken.
- Das Land Hessen hat 2014 die Bürgschaft für die erste Bohrung in der Energiesparte tiefe Geothermie übernommen. Nach der Niederbringung der ersten Bohrung sind seismische Ereignisse in Hessen aufgetreten.
- Eine weitere atomare Katastrophe, hat die Welt erschüttert. Ein Verkehrflugzeug stürzte im Februar 2012 auf das AKW Forsmark in Schweden. Dadurch wurde die Ostküste Schwedens stark verseucht.
- Die Entwicklung der Speichermedien ist seit 2012 nicht weiter vorangetrieben worden. Es stehen keine rentablen Speichermedien zur Verfügung. Die Investitionen pro KWh-Strom im Bereich der Windenergie haben sich seit 2012 nicht geändert. Die Photovoltaikanlagen besitzen einen Wirkungsgrad von durchschnittlich 25 %, ähnlich dem Wirkungsgrad von 2012.
- Der Stromverbrauch hat im Vergleich zum Jahr 2012 um 20 % abgenommen.
- Der Strompreis ist im Vergleich zum Jahre 2012 gering angestiegen.
- Der Ölpreis ist im Vergleich zum Jahre 2012 moderat gestiegen.

In diesem Szenario werden 350 Millionen kWh_{el} Strom im Jahr 2020 regenerativ im Kreis Groß-Gerau erzeugt. Die Strommenge entspricht 30% des Stromverbrauchs unter den gegebenen Rahmenbedingungen. Das Szenario gestaltet sich wie folgt:

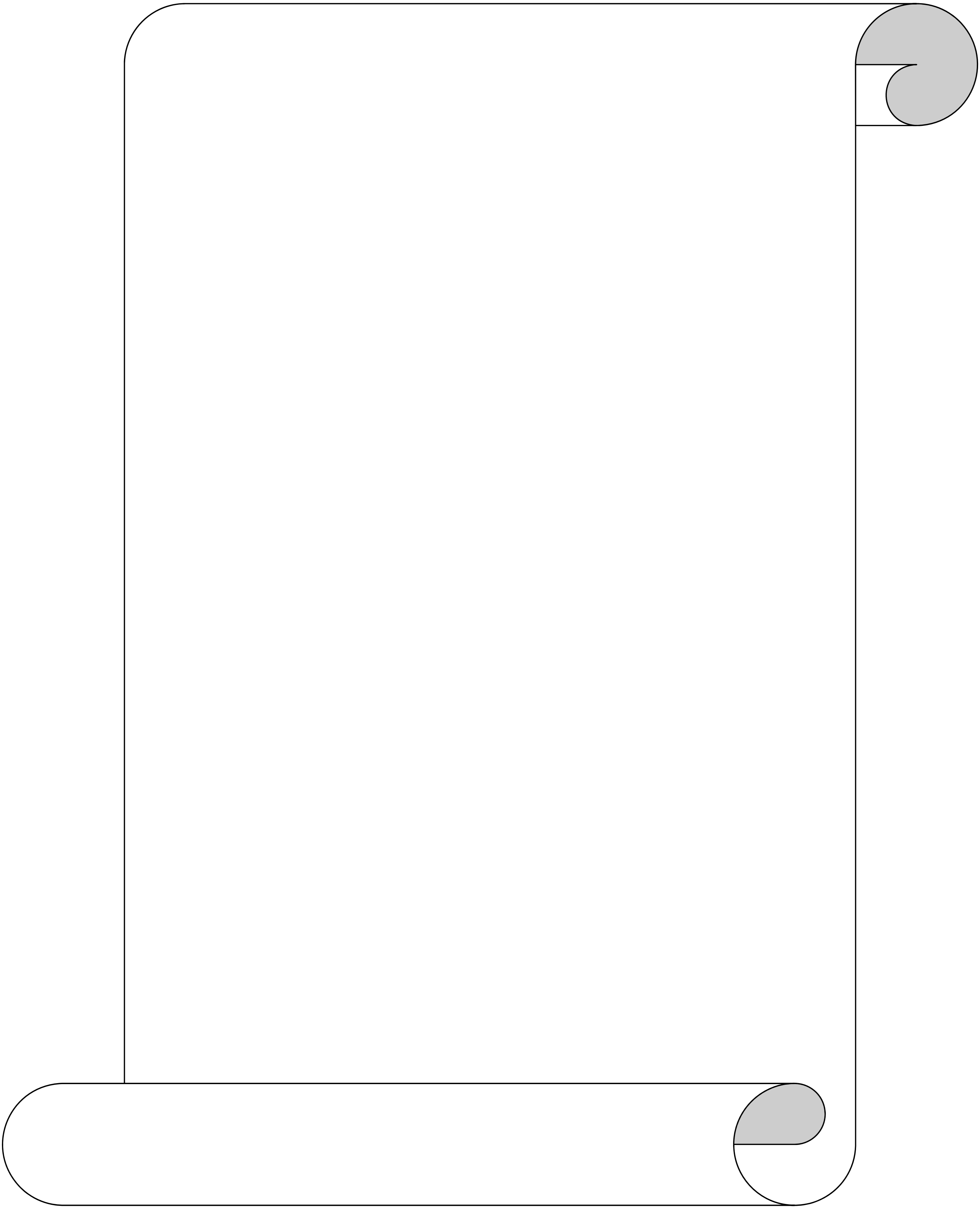


Tabelle G3: Zusammenfassende Darstellung der Regenerativstromproduktion im Jahr 2020 unter den Rahmenbedingungen des Szenarios 2.

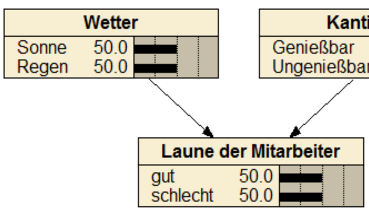
Energiesparte	Regenerativstrom-erzeugung (in Mio. kWh_{el} pro Jahr)	Prozentualer Anteil an Strom-erzeugung (in%)
Photovoltaik	220	18,9
Tiefe Geothermie	0	0
Biomasse	20	1,7
Windkraft	110	9,4
Gesamt	350	30

2.3 Bayes´sche Netze

Während des abschließenden Workshops wurden drei verschiedene Bayes´sche Netze genutzt. Bayes´sche Netze sind kausale Netze, benannt nach dem englischen Mathematiker Thomas Bayes. Sie zeigen Zusammenhänge in einem System über Auftretenswahrscheinlichkeiten an und bieten die Möglichkeit, das Wissen über ein System kompakt darzustellen. Die Netze eignen sich sehr gut, um die Effektivität von Handlungen bzw. Managementmaßnamen zu vergleichen.

2.3.1 Kurze Einführung Bayes´sche Netze

Bayes´sche Netze (hier ein Beispiel in Abbildung) bestehen aus verschiedenen Knoten (Wetter, Kantinenessen und Laune der Mitarbeiter) mit ihren Ausprägungen (Sonne, Regen; genießbar, ungenießbar; gut, schlecht), der Struktur des Netzes (Wetter und Kantinenessen sind die Elternknoten von Laune der Mitarbeiter und wirken (mit Pfeilen) auf die Laune der Mitarbeiter) und bedingten Wahrscheinlichkeitstabellen.



Wetter	Kantinenessen	gut	schlecht
Sonne	Genießbar	80	20
Sonne	Ungenießbar	60	40
Regen	Genießbar	40	60
Regen	Ungenießbar	10	90

Abbildung G2: Beispiel Bayes´sche Netz zur Laune der Mitarbeiter mit der zugehörigen bedingten Wahrscheinlichkeitstabelle für den Knoten „Laune der Mitarbeiter".

Bayes´sche Netze bieten die Möglichkeit, die Auswirkungen von Ereignisses oder Zuständen auf ein anderes Ereignis bzw. einen anderen Zustand zu berechnen. In unserem Beispiel (Abbildung) geht man davon aus, dass das Wetter und das Kantinenessen Auswirkung auf die Laune der Mitarbeiter hat. Scheint z.B. die Sonne und ist das Kantinenessen genießbar, dann ist die Wahrscheinlichkeit, wenn wir uns auf diese beiden Einflussfaktoren konzentrieren, dass die Laune unter den Mitarbeitern sehr gut ist, mit 80% relativ hoch. Anhand des Bayes'schen Netzes in Abbildung 2 oben kann dann, mit den in Abbildung 2 unten gegebenen bedingten Wahrscheinlichkeiten, berechnet werden, dass die Wahrscheinlichkeit, das die Laune der Mitarbeiter gut ist, bei 50% liegt, wenn es gleich wahrscheinlich ist, dass die Sonne scheint oder es regnet, und dass das Kantinenessen genießbar oder ungenießbar ist. Die probabilistischen Zusammenhänge zwischen den Knotenvariablen werden in den bedingten Wahrscheinlichkeitstabellen für alle möglichen Kombinationen der Ausprägungen der Elternknoten definiert. Für die quantitative Beschreibung dieser Ursache-Wirkungsbeziehungen können in den Bayes´schen Netzen verschiedene Quellen genutzt werden. Neben den Einschätzungen von Experten können auch Daten aus der Literatur oder Statistiken in die Bayes'schen Netze einfließen.

2.3.2 Bayes´sche Netze und Wahrscheinlichkeitsverteilungen in den Zielknoten

Im partizipativen Prozess wurden die kausalen Netze für die Energiesparten Photovoltaik, tiefe Geothermie und Windenergie in den Workshop eingebracht. Neben dem Vergleich verschiedener Handlungen wurden die im Rahmen des Prozesses erstellten Szenarien mit den Bayes´schen Netzen durchgespielt. Die Netze beruhen alle auf der Annahme, dass der Stromverbrauch im Jahr 2020 um 20% gesunken ist und insgesamt im Kreis Groß-Gerau eine Mio. MWh/a beträgt. Das Ziel des Kreises ist es, 300 000 MWh/a Strom aus erneuerbaren Energien zu erzeugen im Vergleich zu ca. 18 000 MWh/a im Jahr 2011. Die drei Bayes´schen Netze (Abbildung G, 4 und 5) zeigen alle eine vergleichbare Struktur. Sie besitzen alle einen Zielknoten (orange), verschiedene Rahmenbedingungen (grün) und im Laufe des Prozesses identifizierte Handlungen (blau). Die Rahmenbedingungen entsprechen den erstellten Szenarienrahmen. Anschließend an jedes Netz finden sich Tabellen, die die Wahrscheinlichkeitsverteilung des Zielknotens beim Durchführen verschiedener Handlungen und damit ihre Auswirkung auf die Regenerativstromerzeugung im Kreis Groß-Gerau für die jeweiligen Bayes´schen Netze beinhalten. Da es sich bei den angegebenen Wahrscheinlichkeiten aufgrund mangelnder Daten um grobe Schätzungen handelt, ist ihre Aussagekraft begrenzt. Jedoch ist es anhand der Wahrscheinlichkeiten möglich, Tendenzen der Auswirkungen verschiedener Handlung anschaulich darzustellen.

Die Bayes´schen Netze zur Photovoltaik und Windenergie basieren zum einen auf Expertenmeinungen. Für das Bayes´sche Netz zur Photovoltaik wurden drei und zum Bayes´schen Netz der Windenergie zwei Experten befragt. Zum anderen wurden Angaben aus Literatur genutzt, um die Wahrscheinlichkeitstabellen einzelner Knoten auszufüllen. Die Wahrscheinlichkeitsverteilung im Bayes´schen Netz zur tiefen Geothermie basiert ausschließlich auf Expertenmeinungen. In der folgenden Tabelle findet sich eine Übersicht zu den genutzten Studien

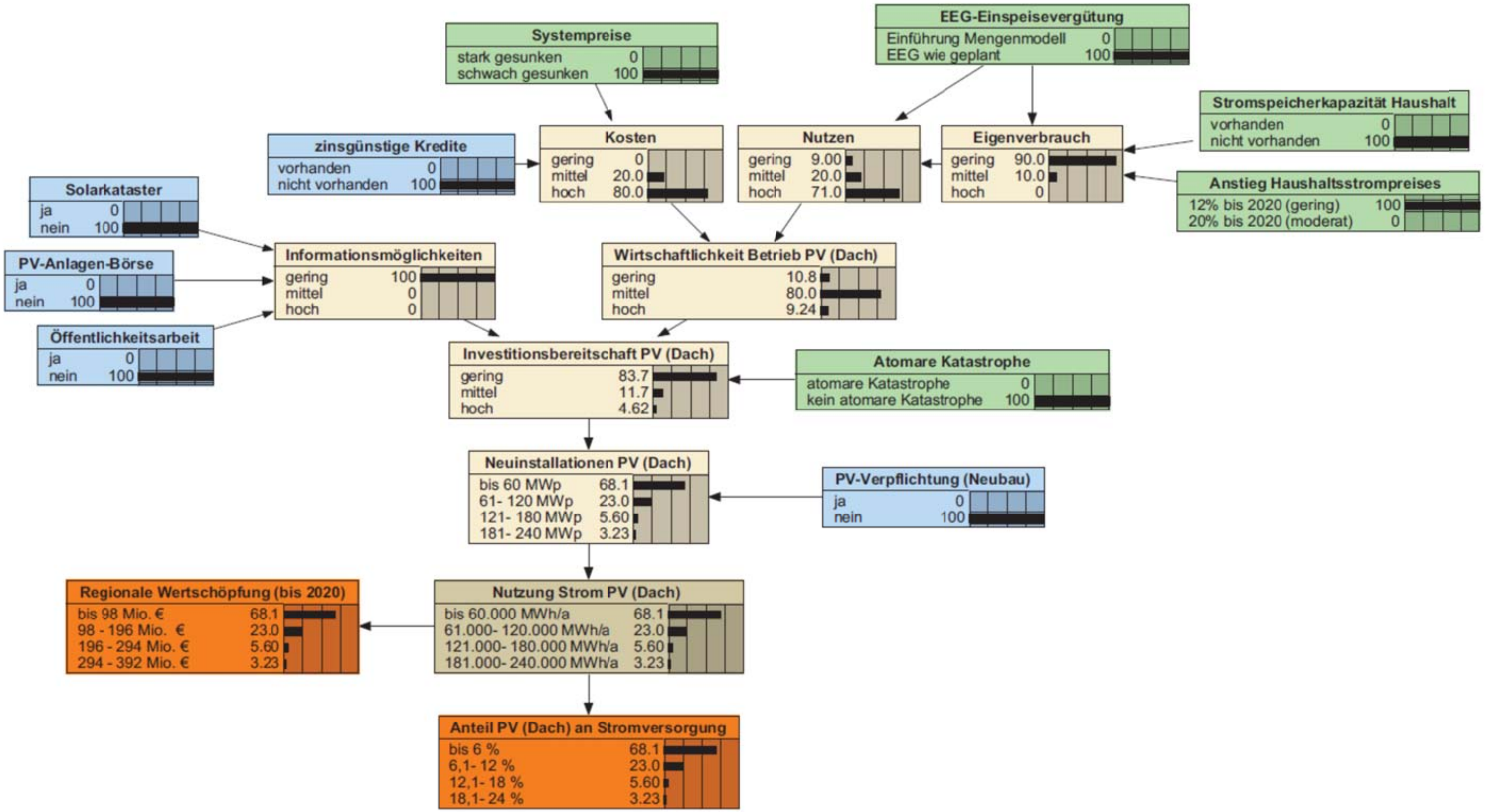


Abbildung G3: Bayes´sches Netz zur Regenerativstromerzeugung aus Photovoltaikanlagen auf Dachflächen im Kreis Groß-Gerau. Das Netz beinhaltet Zielknoten (orange), Rahmenbedingungen entsprechend der Szenarienrahmen (grün) und Handlungsoptionen (blau). Das Netz zeigt die Wahrscheinlichkeitsverteilung im Szenario 2, wenn keine der Handlungen ausgeführt wird.

Tabelle G4 ist zu entnehmen, dass die Handlungen H1 (Öffentlichkeitsarbeit) und H5 (PV-Verpflichtung auf Neubauten) die effektivsten Handlungen im Landkreis Groß-Gerau sind. Beim Ergreifen dieser beiden Handlungen sind die Wahrscheinlichkeiten für einen sehr kleinen Anteil Regenerativstromanteil von 0-6% am geringsten (bei H1: 40% und bei H5: 34%). Die Handlungen H2 und H3 haben die gleiche Wirkung auf den Anteil Regenerativstrom aus PV-Dachanlagen. Das Durchführen aller Handlungen führt verständlicher Weise zu der jeweils höchsten Wahrscheinlichkeit für die Anteile 12,1-18% und 18,1-24%.

Tabelle G4: Wahrscheinlichkeitsverteilungen des Zielknotens „Anteil PV (Dach)" an der Stromversorgung beim Durchführen verschiedener Handlungen unter den beiden Szenarienrahmen 1 und 2 (Handlung 1: Öffentlichkeitsarbeit (H1), Handlung 2: PV-Anlagen-Börse installieren (H2), Handlung 3: Solarkataster erstellen (H3), Handlung 4: zinsgünstige Kredite bereitstellen (H4), Handlung 5: PV-Verpflichtung auf Neubauten (H5)).

	Anteil (%)	keine H	H1	H2	H3	H4	H5	alle H
Szenario 1	0 - 6	56	40	49	49	52	34	8
	6,1 – 12	24	27	25	25	24	34	25
	12,1 – 18	10	17	13	13	12	20	37
	18,1 – 24	10	16	13	13	12	12	30
Szenario 2	0 - 6	55	42	50	50	51	33	11
	6,1 – 12	25	27	26	26	24	35	27
	12,1 – 18	11	16	13	13	12	21	36
	18,1 – 24	9	14	11	11	13	11	26

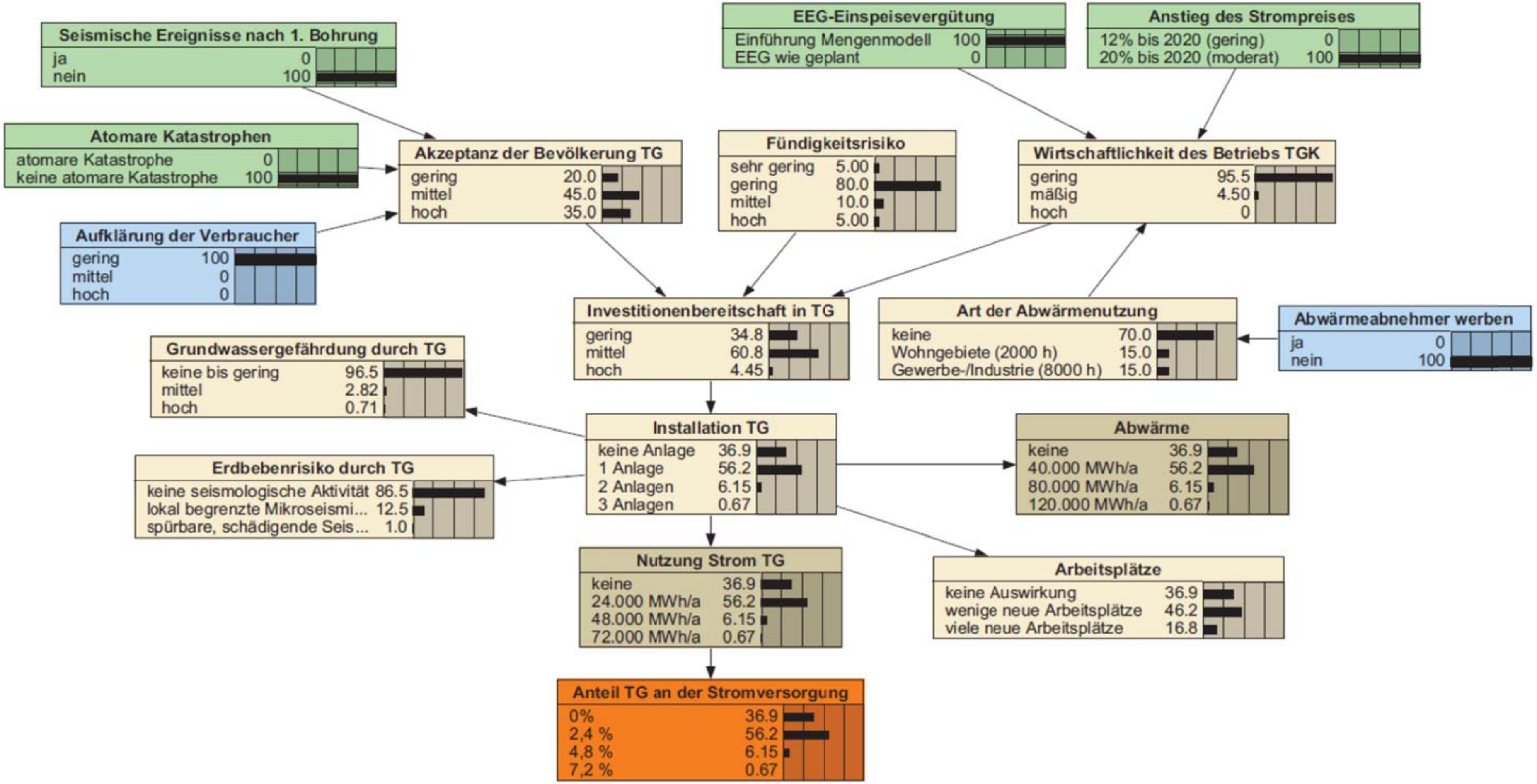


Abbildung G4: Bayes´sches Netz zur Regenerativstromerzeugung aus tiefer Geothermie (TG) im Kreis Groß-Gerau. Das Netz beinhaltet einen Zielknoten (orange), Rahmenbedingungen entsprechend der Szenarien (grün) und Handlungsoptionen (blau). Das Netz zeigt die Wahrscheinlichkeitsverteilung, wenn keine der Handlungen ausgeführt wird.

Tabelle G5 macht deutlich, dass bei Eintritt seismischer Ereignisse (Szenario 2) die tiefe Geothermie als alternative Energiequelle wegfallen würde. In Szenario 2 wird deutlich, dass die Aufklärung der Verbraucher (H1) nicht generell zu Erhöhung der Wahrscheinlichkeit für den Bau eines tiefengeothermischen Kraftwerks führt. Das Bayes´sche Netz verdeutlicht hier die Problematik, dass aufgeklärte Verbraucher möglicherweise das Projekt stärker hinterfragen, als nicht aufgeklärte Verbraucher. Das Netz bzw. auch die Tabelle machen deutlich, dass die Handlungen von Akteuren neben den Erlaubnisfeldinhaber im Bereich der tiefen Geothermie beschränkt sind.

Tabelle G5: Wahrscheinlichkeitsverteilungen des Zielknotens „Anteil TG an der Stromversorgung" beim Durchführen verschiedener Handlungen (Handlung 1: Aufklärung der Verbraucher hoch (H1), Handlung 2: Abwärmeabnehmer werben (H2)).

	Anteil TG (%)	keine H	H1	H2	alle H
Szenario 1	0	37	**47**	35	46
	2,4	56	**47**	53	44
	4,8	6	**5**	10	9
	7,2	1	**1**	2	1
Szenario 2	0	**74**	**77**	**73**	**76**
	2,4	22	21	20	20
	4,8	3	2	6	3
	7,2	1	0	1	1

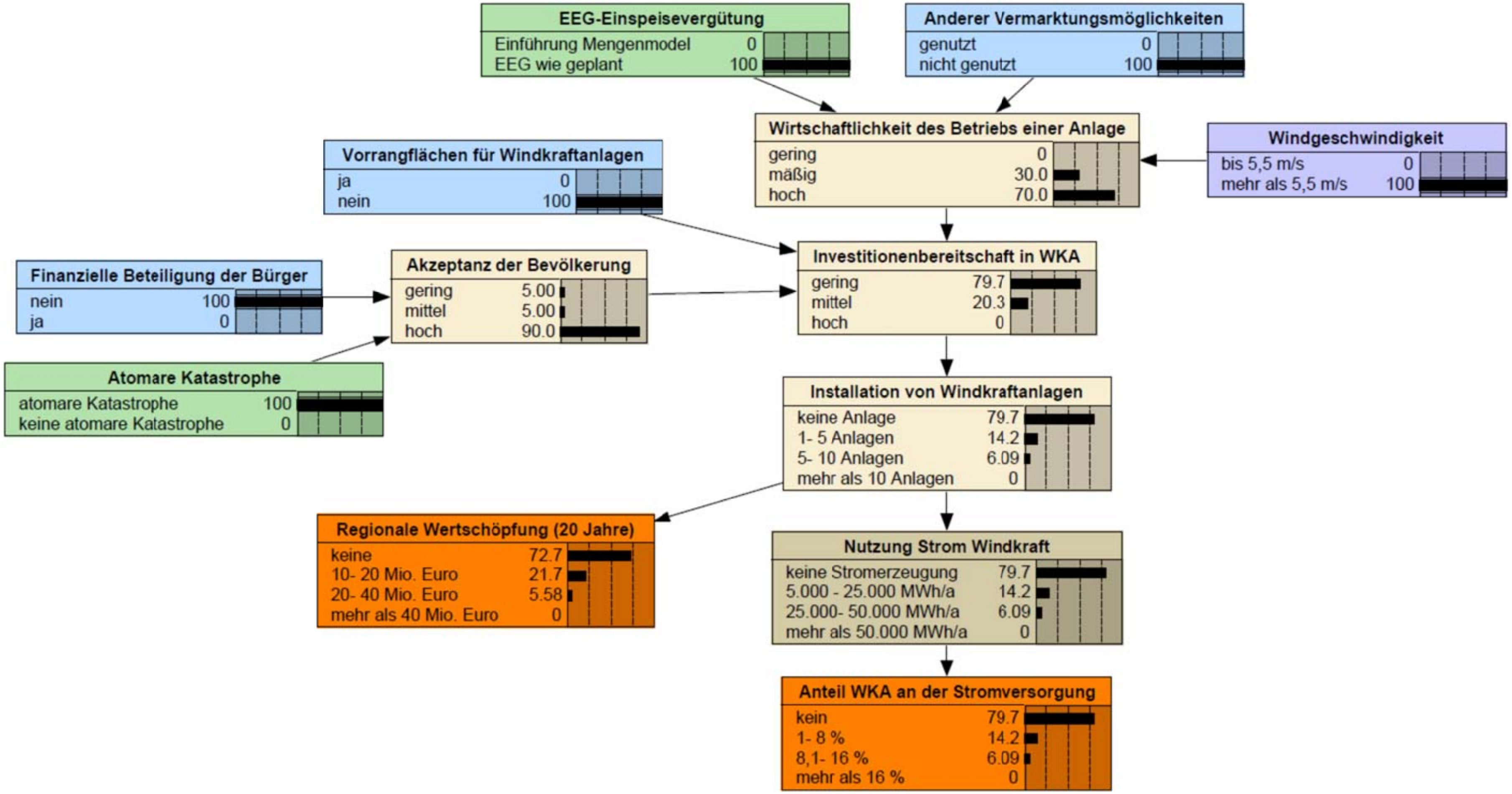


Abbildung G5: Bayes´sches Netz zur Regenerativstromerzeugung aus Windkraftanlagen (WKA) im Kreis Groß-Gerau. Das Netz beinhaltet Zielknoten (orange), Rahmenbedingungen entsprechend der Szenarien (grün) und Handlungsoptionen (blau). Das Netz zeigt die Wahrscheinlichkeitsverteilung, wenn keine der Handlungen ausgeführt wird.

Tabelle G6 beschreibt H2, die Ausweisung von Vorrangflächen für Windkraftanlagen, als die wichtigste Handlung. Das Ausweisen von Vorrangflächen stellt die Voraussetzung für den Bau von Windkraftanlagen (WKA) dar. Aufgrund der Windverhältnisse im Kreis Groß-Gerau spielt die Windhöffigkeit eine zentrale Bedeutung für den Bau einer WKA. Fehlende Windgeschwindigkeiten stellen verständlicher Weise ein k.o.-Kriterium für den Bau einer WKA dar. Detaillierte Windmessungen müssen vorgenommen werden.

Tabelle G6: Wahrscheinlichkeitsverteilungen des Zielknotens „Anteil WKA an der Stromversorgung" beim Durchführen verschiedener Handlungen (Handlung 1: Finanzielle Beteiligung der Bürger (H1), Handlung 2: Vorrangflächen ausweisen (H2), Handlung 3: Andere Vermarktungsmöglichkeiten nutzen (H3))

	Anteil	keine H	H1	H2	H3	alle H
Szenario 1	0%	97	97	**30**	94	26
	1 - 8%	2	2	**39**	4	40
	8,1, - 16%	1	1	**21**	2	22
	> 16%	0	0	**10**	0	12
Szenario 2	0%	80	79	**5**	77	2
	1 - 8%	14	15	**49**	16	50
	8,1, - 16%	6	6	**29**	7	29
	> 16%	0	0	**17**	0	19

2.4 Entwickelte Handlungsoptionen

Der abschließende Workshop des partizipativen Prozesses fand am 13.11.2012 bei den Riedwerken in Groß-Gerau statt. Während des Workshops erarbeiteten die Teilnehmer Handlungsoptionen. In Tabelle aufgelisteten. Die Handlungen sind übersichtlich nach Energiesparten sortiert. Es werden die einzelnen Handlungen kurz erläutert und die zuständigen Akteure angegeben (Tabelle G7).

Tabelle G7: Durch Workshop-Teilnehmer priorisierte Handlungen mit Angabe einer kurzen Erläuterung und den zuständigen Akteuren.

Energie-sparte	Handlung	Erläuterung (auch mögliche Hemmnisse)	Zuständige Akteure
Tiefe Geothermie	Genehmigungsverfahren unterstützen	Eine tiefengeothermische Anlage wird bisher noch nicht im Kreis Groß-Gerau betrieben. Daher fehlt es an Erfahrungen hinsichtlich der geforderten Genehmigungsverfahren auf Seiten der Erlaubnisfeldinhaber und der zuständigen Behörden im Kreis Groß-Gerau. Eine kooperative Zusammenarbeit ist gefordert. Die ÜWG wünscht zusätzlich eine öffentliche Befürwortung der tiefen Geothermie von Seite des Kreises.	ÜWG, Kreis, Kommunen
Photovoltaik	Freiwillige Selbstverpflichtung für PV-Anlagen auf öffentlichen Gebäuden	Eine freiwillige Selbstverpflichtung für PV-Anlagen auf öffentlichen Gebäuden führt zu einer Vorbildfunktion der öffentlichen Hand für die Einwohner im Kreis Groß-Gerau. Als Hemmnis treten hier mögliche leere Haushaltskassen der öffentlichen Verwaltung auf.	Kreis, Kommunen
	Verpflichtung PV über städtebaulichen Vertrag auf Neubauten	Die Verpflichtung beinhaltet die Nutzung von PV-Anlagen auf Dachflächen von Neubauten. Möglicherweise führt diese Verpflichtung zu weniger Neubauten. Die aktuelle Gesetzeslage (HBO) lassen keine Verpflichtungen zu.	Kommunen
	Bewerbung PV für private Haushalte	Die Bewerbung der PV kann beinhalten, dass die Nutzung des Eigenbedarfs beim Anstieg des Strompreises attraktiv wird.	Kommunen, Energieversorger, Kreditinstitute
Windenergie	Vorrangflächen ausweisen	Im Land Hessen sollen insgesamt 2% der Landesfläche als Vorrangflächen ausgewiesen werden. Die Kommunen sind aktuell gefragt, Vorschläge für geeignete Flächen zu machen, die dann im Regionalplan berücksichtigt werden. Die Windhöffigkeit auf diesen Flächen sollte mindestens 5,75 m/sec betragen.	Kreis, Kommunen
Energieeinsparung	Anreize zur Energie-einsparung schaffen	Möglicher Anreiz könnte hier die finanzielle Förderung von verbrauchsarmen Elektrogeräten sein. Der Erfolg der Energieeinsparung ist immer an die Bereitschaft der Akteure geknüpft.	
	Aufsuchen von Energieberatern	Um Verbraucher im Kreis Groß-Gerau zum Thema Energieeinsparung gut beraten zu können, sollten die Mitarbeiter der Energieversorger und Kommunen durch Energieberater entsprechend geschult werden.	Kommunen, Energieversorger

Energie-versorgungs-system	Integrierte Versorgungssysteme forcieren (Berücksichtigung von KWK und Wärmepumpen)	Integrierte Versorgungssysteme wie die Nutzung von Kraft-Wärme-Kopplung und Wärmepumpen sollen im Kreis forciert werden. Der Kreis Musterberechnungen durchführen und die Anbieter beraten.	Kreis, Energie-versorger
	Lastverschiebe-potentiale nutzen	Das Lastverschiebepotential bietet die Möglichkeit, den Verbrauch der Industrie und des Gewerbes auf Tageszeiten zu verschieben, an denen das Stromnetz entlastet werden muss.	Netz-betreiber, Industrie und Gewerbe
	Öffentlichkeitsarbeit betreiben	Hier wurde insbesondere das Durchführen einer Energiemesse genannt. Alle Akteure aus der Energiebranche können sich auf dieser Messe präsentieren.	Alle Akteure

3 Evaluation der partizipativen Strategieentwicklung

Während des Abschlussworkshops wurden die Teilnehmer gebeten, einen Fragebogen zur Evaluation des Prozesses auszufüllen. Im Fokus der Evaluation stehen die eingesetzten Methoden und die Ergebnisse des partizipativen Prozesses. Abbildung zeigt die Legende, die für die Darstellung Evaluationsergebnisse verwendet wird. Insgesamt wurden zehn Fragebögen durch die Teilnehmer am letzten Workshop ausgefüllt und standen für die Auswertung zur Verfügung.

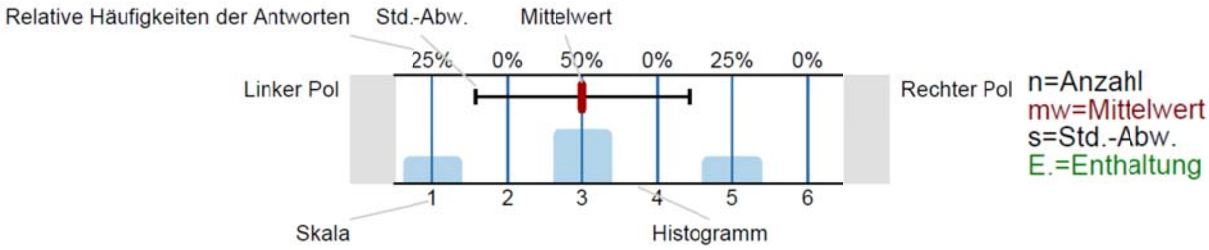


Abbildung G6: Legende zur Darstellung der Evaluationsergebnisse.

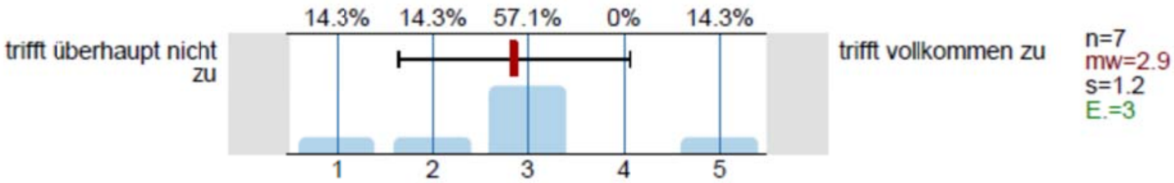
Die Antworten auf die offenen Fragen im Fragebogen sind hier nicht dargestellt. Aus den Antworten auf diese Fragen geht hervor, dass die beteiligten Akteure die Beteiligung weiterer Akteure für sinnvoll erachten. Genannt wurden hier Kirchen, Vereine, Architekten, Kommunen aus dem Nordkreis, Riedwerke (im Hinblick auf die Beurteilung des Biomassepotenzials), Verbraucher, Verbraucherschutzorganisationen und Jugendorganisationen.

Als wichtigste Veranstaltung wurde der Abschlussworkshop von den Teilnehmern wahrgenommen. Es wurde hervorgehoben, dass es in diesem Workshop um konkrete Maßnahmen ging und (hoffentlich) der Grundstein für eine stetige Beteiligung von Akteuren gelegt wurde.

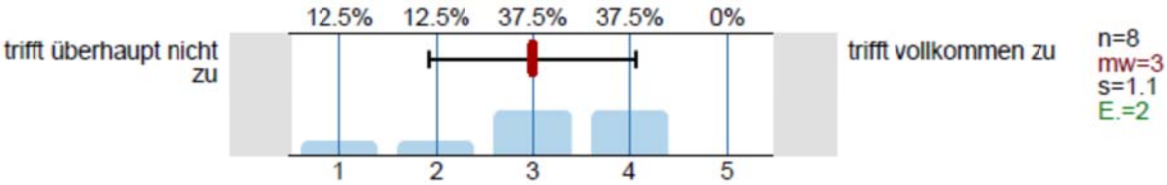
Zusammenfassend zeigen die Ergebnisse auf den folgenden Seiten eine durchschnittlich gute Bewertung der eingesetzten Methoden. Der Mittelwert liegt durchgängig über dem Wert 2,5 auf einer Skala von 1 bis 5, wobei 1 „trifft überhaupt nicht zu“ und 5 „trifft vollkommen zu“ darstellt.

Die Konstruktion und die Anwendung der akteursspezifischen kausalen Netze:

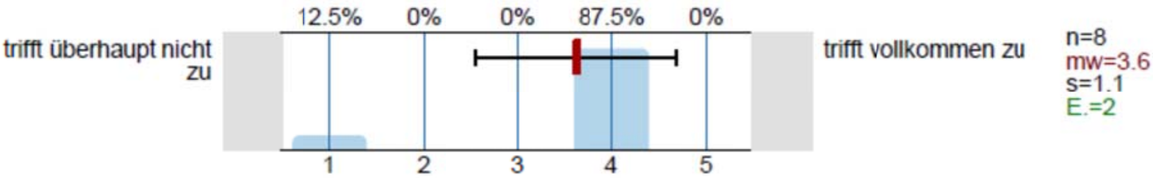
- Hat meiner Organisation geholfen unsere institutionelle Perspektive intern zu reflektieren.



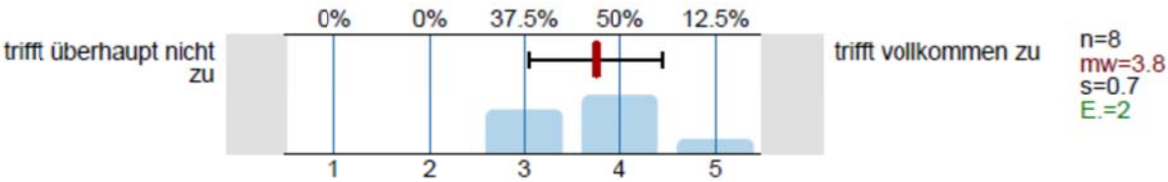
- Hat den anderen Akteuren unsere institutionelle Perspektive verdeutlicht.



- Hat die Perspektive der anderen Interessensgruppen für mich transparent gemacht.

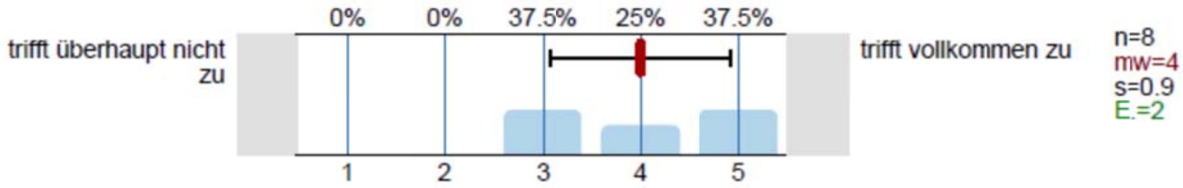


- War für nachvollziehbar und verständlich.

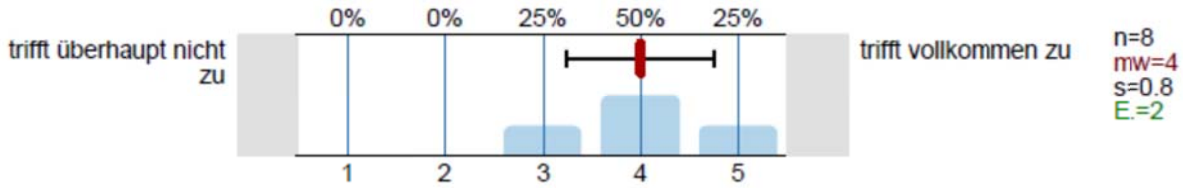


Die Konstruktion und Anwendung der Gesamtnetze:

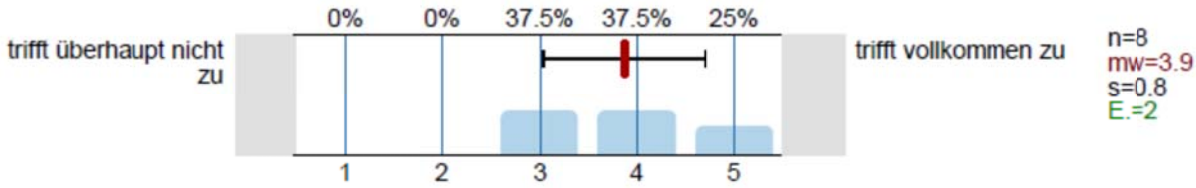
- Hat das Wissen der anwesenden Interessensgruppen zusammengebracht.



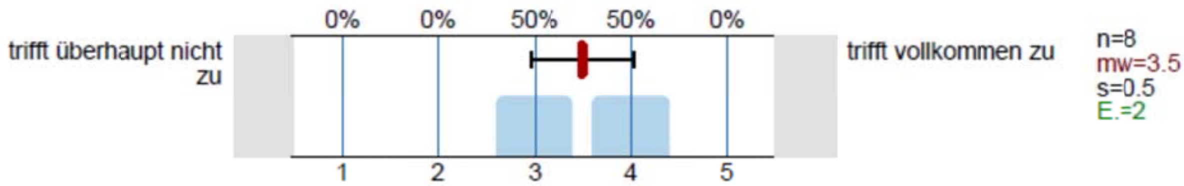
- Hat wichtige Zusammenhänge der Regenerativstromversorgung im Kreis Groß-Gerau verdeutlicht.



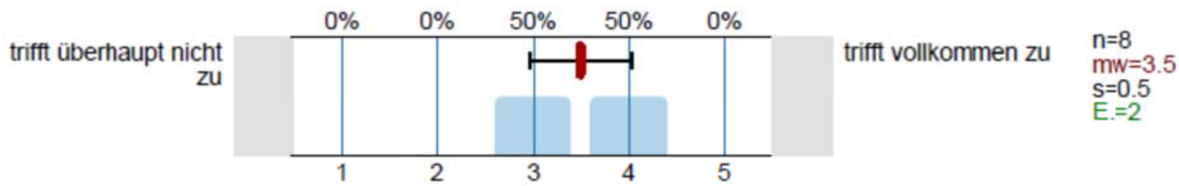
- Hat Handlungsmöglichkeiten der Akteure aufgezeigt.



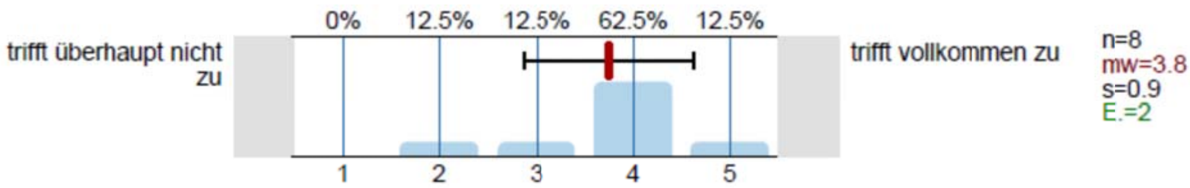
- Hat den anderen Akteuren unsere institutionelle Perspektive verdeutlicht.



- Hat die Perspektive der anderen Interessensgruppen für mich transparent gemacht.

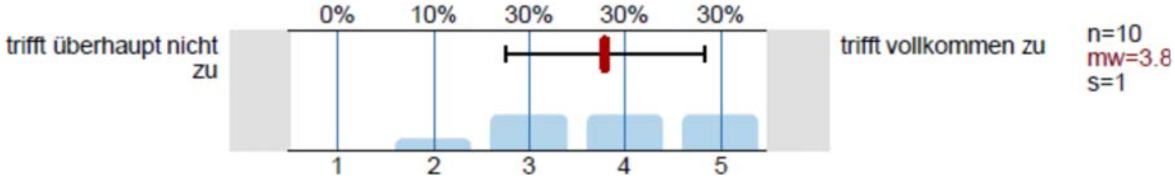


- War für mich nachvollziehbar und verständlich.

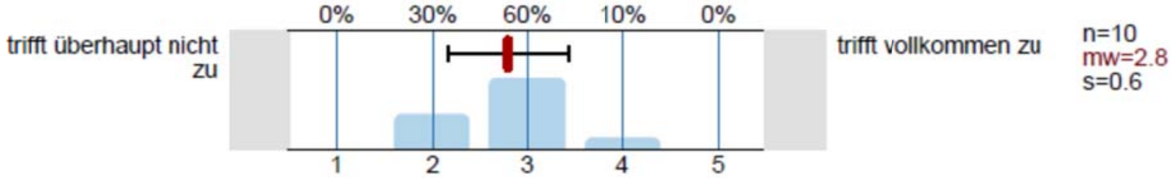


Die Entwicklung von zwei Szenarien:

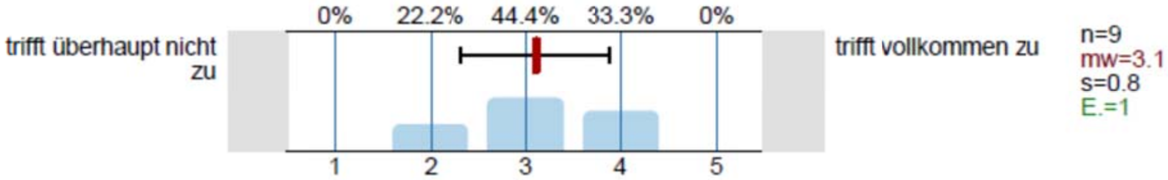
- Hat zum besseren Verständnis externer Einflussfaktoren und deren unsichere Entwicklung geführt



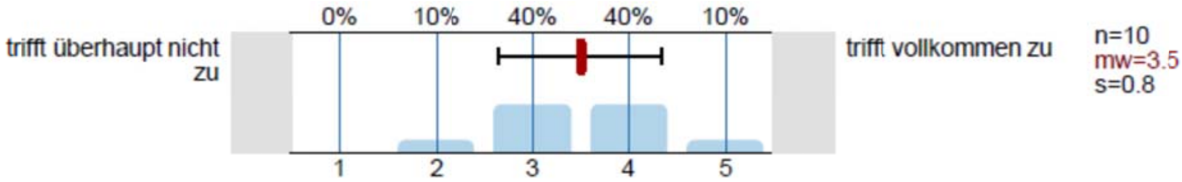
- Hat langfristig robuste Handlungsmöglichkeiten der Akteure aufgezeigt.



- Hat die Perspektive der anderen Interessensgruppen für mich transparent gemacht.

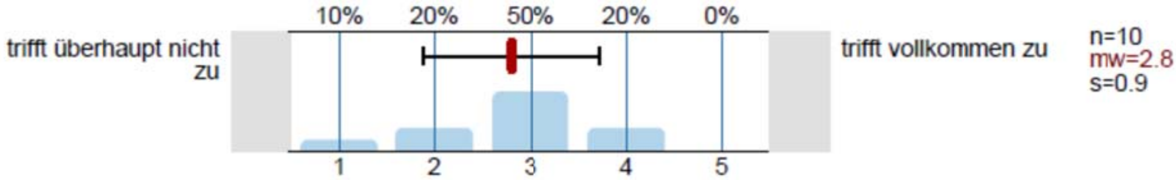


- War für mich nachvollziehbar und verständlich.

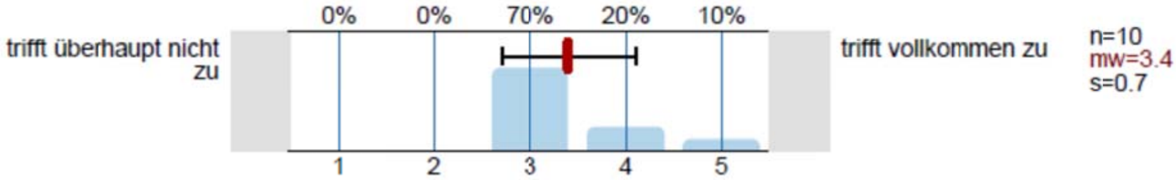


Die Konstruktion und Anwendung der Bayes´schen Netze:

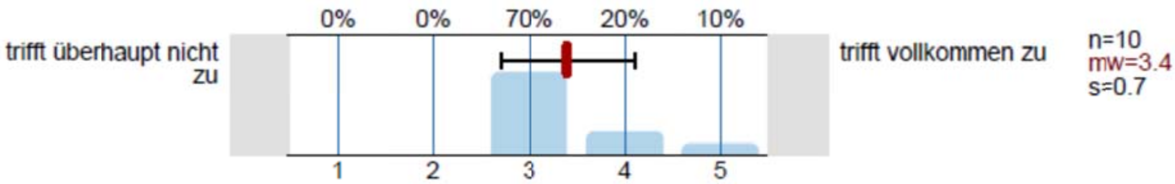
- Hat Wissenslücken oder ein Defizit an Informationen identifiziert.



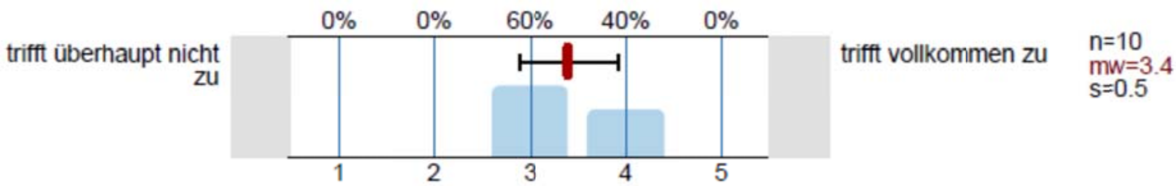
- Hat wichtige Zusammenhänge der Regenerativstromversorgung im Kreis Groß-Gerau verdeutlicht.



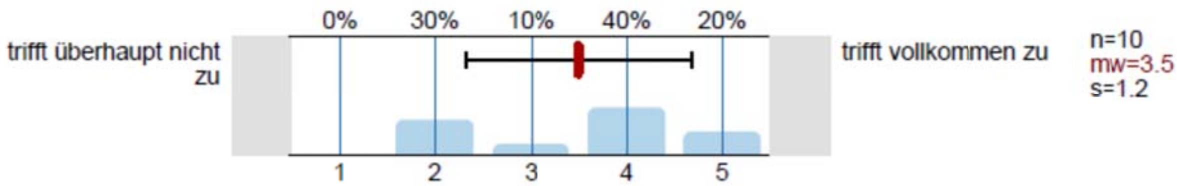
- Hat Handlungsmöglichkeiten der Akteure aufgezeigt.



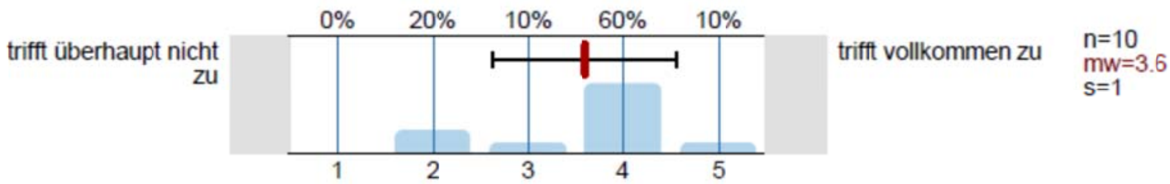
- Hat die Auswahl an Handlungsmöglichkeiten unterstützt.



- Hat Ergebnisse in einem nützlichen Format erzeugt.

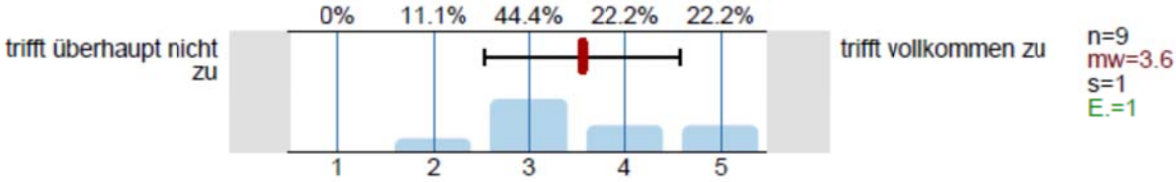


- War für mich nachvollziehbar und verständlich.

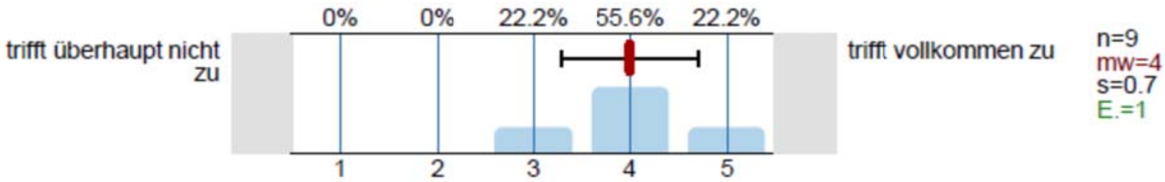


Die verwendeten Methoden:

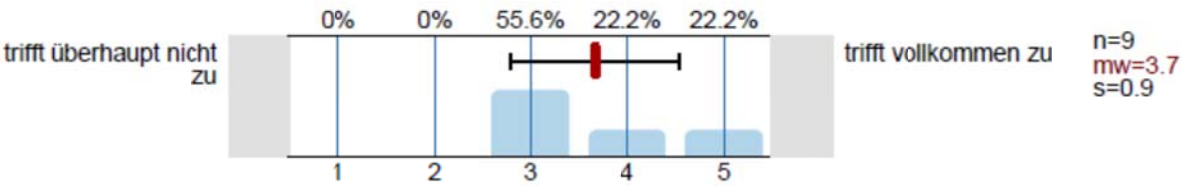
- Haben die Diskussionen inhaltlich besser strukturiert und effizienter gestaltet.



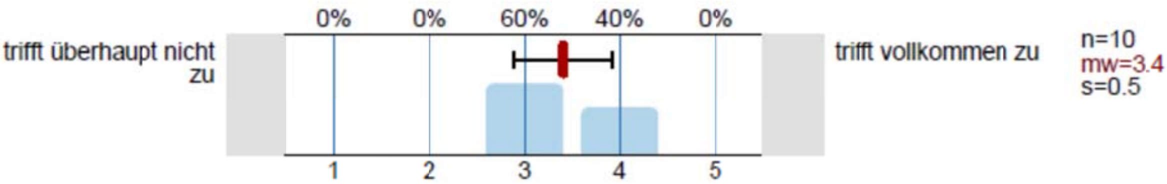
- Haben stärker animiert Informationen auszutauschen und Sichtweisen einzubringen.



- Haben die Perspektiven aller Teilnehmer besser berücksichtigt.

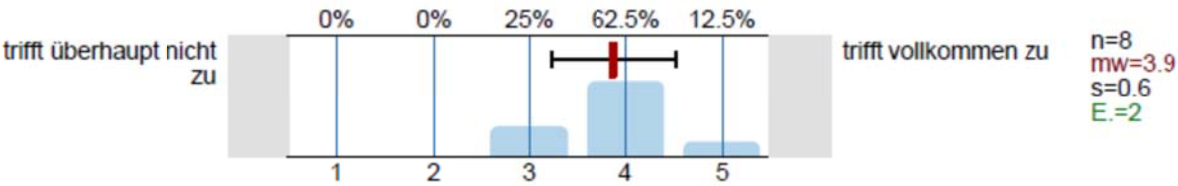


- Haben zu einem höheren Wissenszuwachs bei der einzelnen Teilnehmern geführt.

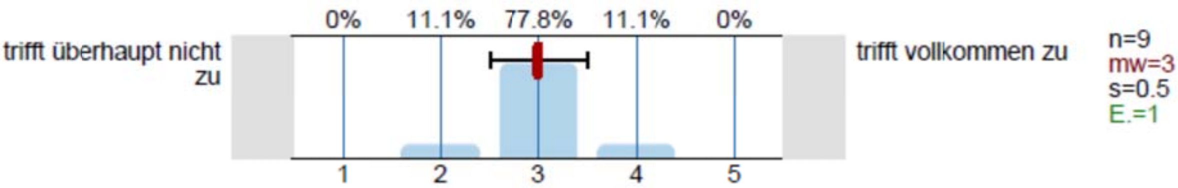


Die entwickelten Strategien:

- Sind in sich stimmig.

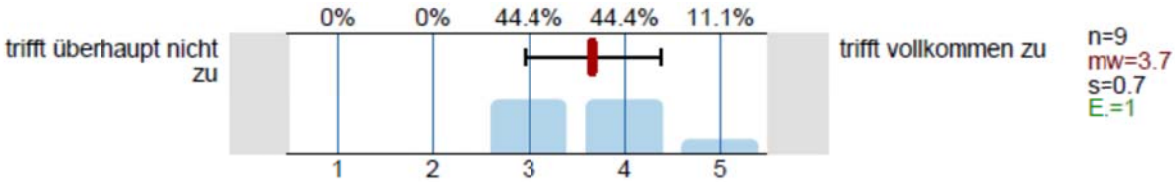


- Sind konkret und umsetzbar.

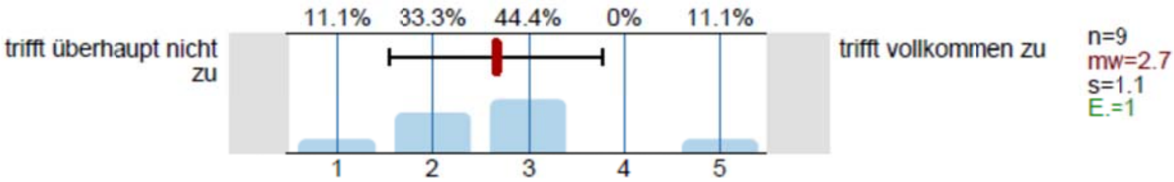


Meine Teilnahme am partizipativen Prozess:

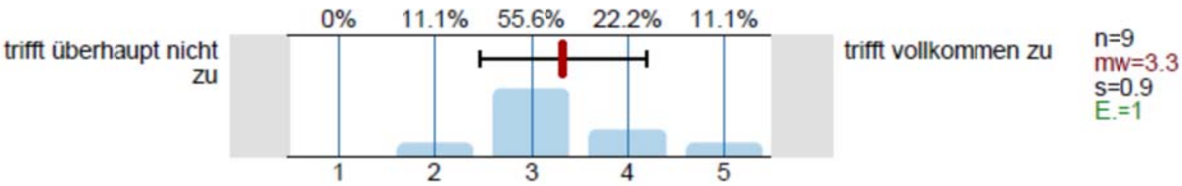
- Hat mein Verständnis für die Anliegen der anderen Teilnehmer vergrößert.



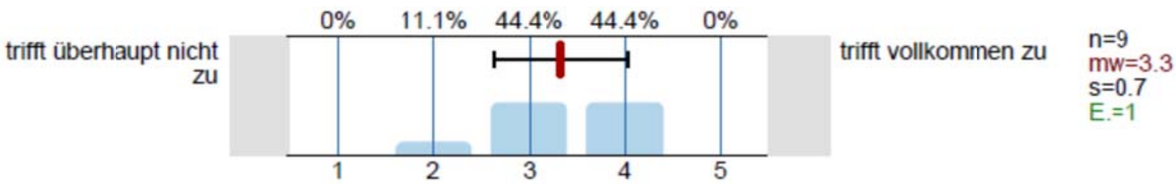
- Hat meine Bereitschaft Informationen mit anderen Teilnehmern zu teilen, erhöht.



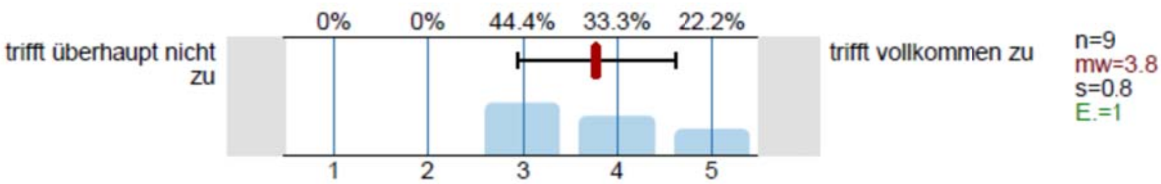
- Hat mein Vertrauen in mögliche zukünftige Projekte gestärkt.



- Hat meine Motivation gesteigert, mich für die Regenerativstromerzeugung im Kreis GG einzusetzen.



- Würden Sie nochmal an einem partiziptativen Prozess teilnehmen?



4 Wünsche und Ideen für die weitere Zusammenarbeit

Die folgenden Wünsche und Ideen für eine weitere Zusammenarbeit wurden durch die Teilnehmer des Abschlussworkshops zusammengetragen.

Gründung eines Beirats auf Basis der Akteursgruppe

Neuer Arbeitskreis: Konkrete Schritte und Praxisbezug

Kontinuierlicher Austausch über energierelevante Themen

Verantwortliche festlegen

Ziele und Maßnahmen in der Umsetzung beobachten und begleiten

Regelmäßiger Halbseiter in der Tagespresse

Best-practice-Beispiele erarbeiten

Engere Verzahnung mit der Wirtschaft

5 Weiterführende Literatur

TabelleG8: Weiterführende Literaturangaben zu Methoden und Inhalten des partizipativen Prozesses.

Thema	Literaturangabe
Akteursmodellierung	Döll & Döll (2008): Modellierung der Problemwahrnehmungen und Handlungen von Akteuren im Problemfeld „Mobile organische Fremdstoffe in Gewässern“ Link: http://www.geo.uni-frankfurt.de/ipg/ag/dl/f_publikationen/2008/Doell_Doell_2008_Akteursbasierte_Modellierung.pdf
Bayes´sche Netze	Jensen, F.V. (2000): An introduction to Bayesian Networks. Fenton, N. & Neil, M. (2007): Managing risk in a modern world. Application of Bayesian Networks. Link: http://www.agenarisk.com/resources/apps_bayesian_networks.pdf
Regenerativstrom-versorgung im Kreis Groß-Gerau	Transferstelle für Rationelle und Regenerative Energienutzung Bingen (2009): Strategiepapier für den Kreis Groß-Gerau zur Zielerreichung: 30% Erneuerbare Energien bis 2020
	Transferstelle für Rationelle und Regenerative Energienutzung Bingen (2010): Zeit- und Maßnahmenplan zur Umsetzung des Ziels 30% Regenerativstrom 2020 – Konkretisierung des Strategiepapiers-
	TU Darmstadt & juwi holding AG (2007): Potenzialstudie erneuerbare Energien für den Landkreis Groß-Gerau (Hessen) - Schwerpunkt Stromerzeugung
Szenarioanalyse	Wikipedia „Szenarioanalyse“ Link: http://de.wikipedia.org/wiki/Szenarioanalyse

TabelleG9: Literatur aus der die bedingten Wahrscheinlichkeiten für die Bayes´schen Netze (Windenergie und Photovoltaik) abgeleitet wurden.

Energie-sparte	Knoten im Bayes´schen Netz	Studien	Inhalt
Photovoltaik	Systempreise der PV-Module	Roland Berger Strategy Consultants & Prognos AG (2010): Wegweiser Solarwirtschaft: PV-Roadmap 2020. Link: http://www.sma.de/fileadmin/content/global/Investor_Relations/Documents/Langversion_roadmap.pdf	Sinkende Systempreise bedeuten einen Rückgang der Systempreise um 48% im Jahr 2020. Das bedeutet ein Rückgang von 2,50 - 2,90 €/Wp auf 1,30 bis 1,50 €/Wp.
	Strompreis	Leipziger Institut für Energie GmbH (2012): Gutachten über die Entwicklung der Preise für Strom und Gas in Baden-Württemberg. Link: http://www.ie-leipzig.com/IE/Publikationen/Studien/IE_Kurzfassung_Preise_BW_20.04.2009.pdf	Werte beschreiben den Haushaltsstrompreis. Bei 12% steigt der Strompreis von 25 cent/kWh auf 28 cent/kWh. 20% entsprechen einem Anstieg auf 30 cent/kWh.
	Regionale Wertschöpfung	Institut für ökologische Wirtschaftsforschung (2010): Kommunale Wertschöpfung durch Erneuerbare Energien. Link: http://www.ioew.de/uploads/tx_ukioewdb/IOEW_SR_196_Kommunale_Wertsch%C3%B6pfung_durch_Erneuerbare_Energien.pdf	Analyse der Wertschöpfungseffekte durch die Technik der erneuerbaren Energien.
	PV-Verpflichtung für Neubauten	Institut für Wohnen und Umwelt GmbH Link: http://www.iwu.de/fileadmin/user_upload/dateien/energie/ake44/IWU-Tagung_17-04-2008_-_Diefenbach_-_Basisdaten.pdf	Die Neubaurate in Deutschland liegt bei 1,1% pro Jahr. Übertragen auf Groß-Gerau bedeutet dies eine Zubaurate von 32 MWp pro Jahr.
Wind	Windhöffigkeit	Windressourcenkarte Hessen Link http://www.energieland.hessen.de/mm/Windpotenzialkarte_Hessen_-_Uebersicht_140m_%28PDF,_980_KB%29.pdf	Modellierte Windgeschwindigkeit in 140 m über NN.