Handbook

fairSTREAM toolkit of co-production methods

with a view to fostering systems thinking and justice assessment

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1 Introduction

One dimension of the fairSTREAM project is focused on creating an inventory of the various participatory methods that IIASA scientists use to involve diverse societal stakeholders in the research process. In this toolkit (and accompanying online resources), we present an introductory overview to each of these methods to explain their basic characteristics and requirements and to illustrate some potential uses and limitations with the intention of making such approaches more visible and accessible to the IIASA research community.

The fairSTREAM project is also working to understand and evaluate how such participatory methods can better support the co-production of actionable knowledge through transdisciplinary research processes that bridge the perspectives and goals of researchers and diverse societal stakeholders. This evaluation process is targeted at improving upon these methods in two major ways: first by adding to their capacity to implement systems thinking, and second by enhancing their attention to the assessment of justice and fairness. By explicitly considering the role of systems thinking in participatory research and co-production, we aim to generate a clear argument for why and how participatory methods are crucial tools for robust systems analysis, and thus for IIASA. By highlighting the importance of dynamics of justice and fairness within co-production processes, we develop a rationale for how an equity and justice research group should operate at an International Institute for Applied Systems Analysis.

1.1 1.1 Why co-production?

Co-production—sometimes used synonymously with co-creation and co-development—is an increasingly mainstream idea in sustainability science associated with a growing array of participatory methods and transdisciplinary research approaches (Norström et al. 2020, Miller and Wyborn 2020). Fundamentally, proponents for co-production posit that meaningful collaboration between researchers and societal stakeholders who are impacted by or make use of research outcomes can improve the quality, legitimacy, and accessibility of research products while heightening potential for knowledge production to support action towards sustainability (or other desired outcomes). By incorporating diverse participants and their varied experiences, perspectives, and values into the research process, co-production responds to the increasing complexity/wickedness of the most pertinent societal challenges including climate change, biodiversity loss, and (natural) resource management. Co-production approaches also work to address the longstanding separation between academia and broader society, with some proponents arguing that such approaches are vital to a new social contract for science (Jagannathan et al. 2020). Moreover, co-production recognizes the politics and other power-laden dynamics intrinsic to research contexts and knowledge production and works to bring such dynamics into explicit consideration. Such objectives are clearly well aligned with IIASA's orientation towards policy-relevant and publicly engaged science that supports sustainability transitions in an array of complex systems and settings.

Conceptually, co-production has developed across at least several different disciplines, including public administration, science and technology studies, and sustainability science (Miller and Wyborn 2020).

The uses of the concept and the various methodological approaches associated with its implementation continue to vary widely across disciplines; however, efforts to identify key aspects and principles for knowledge co-production and the evaluation of its effectiveness have recently emerged in the sustainability science literature (Norström et al. 2020, Jagannathan et al. 2020). Norström et al. outline four overarching and related principles for co-production processes. Accordingly such processes should be:

1) context-based—"situate the process in a particular context place or issue",

2) pluralistic—"explicitly recognize the multiple ways of knowing and doing",

3) goal-oriented—"articulate clearly defined, shared and meaningful goals that are related to the challenge at hand", and

4) iterative—"allow for ongoing learning among actors, active engagement and frequent interactions" (2020, pg. 184).

Through the application of such principles, "methods for co-producing knowledge support representatives of different thought collectives in better understanding each other's ways of thinking and in relating their thought styles to each other to jointly generate something new" (td-net 2021). In this framing, thought collectives are specific groups of people that have similar operational categories and terminology (e.g. farmers or biologists) and/or share similar values and/or hold similar worldviews. Co-production methods help bridge these different thought styles (i.e. they are pluralistic) around a particular context, issue or problem. For this purpose, such methods need to be broadly accessible (i.e. they use low-tech equipment and everyday language); they should work towards developing shared understanding or identifying specific points of agreement or disagreement; and they should allow for joint production of specific goals and desired research outcomes in line with the principles above.

Many participatory methods may qualify as co-production methods if they adhere to the above principles and criteria thus be transformed into co-production methods.

1.2 1.2 System dynamics and justice in co-production

Systems thinking is another approach to honor the complexity of grand societal challenges mentioned above, that for this very reason has recently received renewed attention (Seibert 2018). We believe systems thinking may contribute to improving and structuring co-production methods in a productive way. On the one hand by teaching and improving systems thinking skills among participants, as well as by creating systematic and transparent processes and results.

Participation has been an important aspect of systems thinking since at least Jay Forrester (Kirali and Miskolczi 2019), however, whether participatory approaches in systems thinking and particularly systems dynamics can be considered co-production has not been established. While we will not be able to fill this gap completely, in fairSTREAM, we would like to establish an analytical framework that will help establish to what a co-production method can be considered systems thinking and identify easy

ways to include more systems thinking into co-production processes, without turning the existing approach into a fundamentally different or new method.

Finally, ideas of justice are receiving widespread attention these days, as real and perceived injustices prove important barriers to the implementation of sustainable development policies. Justice issues are inherent in all decision making, albeit with varying potential for disagreement and conflict. Justice, both in terms of recognition and procedure can be an issue of co-production processes, in that the extent to which both aspects are realized determines in part the extent to which an engagement process can be considered co-production (cf. pluralism above). However, more importantly here, we intend to determine to what extent co-production processes are suited to assess justice, and to provide guidance on justice assessment by means of co-production processes.

2 Reference – systems thinking to operationalize systems analysis

At IIASA, systems analysis has always been defined broadly and in close relation with policy analysis. For example, former IIASA director Leen Hoordijk suggests:

> *"Systems analysis at IIASA is, in fact, a problem-solving process in which many people take part: scientists of relevant disciplines, stakeholders, and decision makers. These are not just problems per se, but problems along with all the attendant factors and concepts they encompass. To quote Quade and Miser, these factors include: "the knowledge and methods of modern science and technology, in combination with concepts of social goals and equities, elements of judgment and taste, and appropriate consideration of the larger contexts and uncertainties that inevitably attend such systems."*

Such a description is in fact quite close to our definition of co-production. Yet, we argue that it is too all-encompassing to be useful, i.e., it just highlights the sheer breadth of what is needed to analyze a problem but does little to define the more concrete dimensions of systems analysis. Nowadays such high-level categories apply to much interdisciplinary research in sustainability science and global change research. But then is all such work automatically considered systems analysis?

Systems thinking and system dynamics provide the most explicit operationalization of what systems analysis entails. In practice, systems thinking means **bounding** the system of interest, then **exploring** its components and connections and eliciting potentially vastly different stakeholder and problem owner perspectives. It also means exploring different methodologies and tools for **designing and implementing** robust and effective policies in the system of interest.

Arnold and Wade (2015) visualize systems thinking using what they call strong and weak connections;for an adapted version see Figure 1. According to their synthesis of systems thinking literature, the approach starts with understanding the system structure including recognizing interconnections, as well as identifying and understanding when interconnections form feedback-loops. These are considered the most fundamental systems thinking skills. Considering how this structure behaves leads to understanding dynamic behavior, including the differentiation of stocks, flows and variables, and identifying and understanding non-linear relationships. These elements 1-5 are the main route through

the concept map in Figure 1: A concept map of systems thinking. Adapted and expanded from Arnold and Wade (2015).

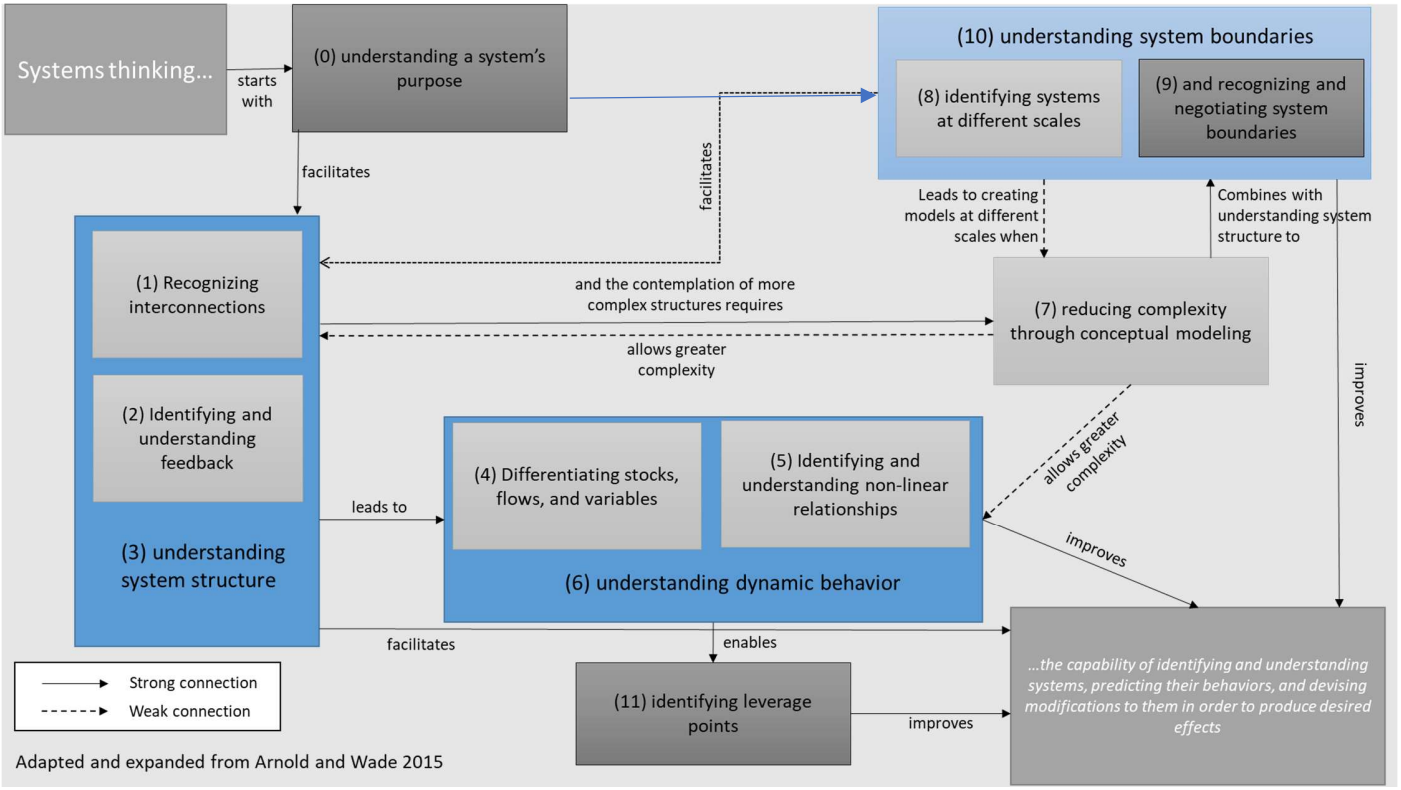

Figure 1: A concept map of systems thinking. Adapted and expanded from Arnold and Wade (2015).

To this route, we introduce an additional preliminary stage to understanding system structure: identifying systems' purpose. System purpose aligns with the idea of problem framing in transdisciplinary research. The rationale for including this step is that co-production happens most importantly on complex issues with no unique problem framing or solution. Therefore, the purpose of a system may be contested and needs to be unraveled and specified for each situation. It should be determined in a co-production setting, so that any further interaction is appropriate and targeted. At this point additional stakeholders might be identified.

Apart from the main elements, 'Creating conceptual models' (Element 7) is another aspect of systems thinking that shall not be confused with applying conceptual models but refers to the ability to create different views of parts of the systems, transforming them, with the aim to reduce complexity. It is an intuitive skill that "… theoretically allows the interpretation of greater complexity as the mind holds less detail about each whole." (Arnold and Wade 2015). 'Understanding a system's purpose (Element 0) is tightly linked to 'understanding system boundaries' (Element 10). Exploring boundaries is an important task that co-production can perform due to the diverse participants and perspectives. Understanding systems at different scales (Element 8) means exactly that, it considers that systems may be delineated very differently, depending on the purpose, however, they are often nested, (see also Ostrom, 2007, on

socio-ecological systems). However, we expand Arnold and Wade's element with the ability to recognize and negotiate system boundaries, which is frequently a topic when considering diverse worldviews in co-production processes. Finally, we make the potential for identifying leverage points another explicit element of this operationalization of systems thinking as it is crucial for co-production and identifying management options.

We examine a selection of co-production methods, vis a vis this operationalization of systems thinking, to assess how explicitly they can analyze systems, beyond the fact that co-creation, by Leen Hordijk's definition, does systems analysis. For each method, we will consider the following questions.

1. Does the method explicitly give instructions as to problem framing, i.e. system purpose and boundaries?
2. Does the method explicitly emphasize thinking about systems structure (i.e. highlight causal relationships and feedbacks)?
3. Does the method explicitly emphasize dynamic behavior (e.g. institutional change in managing a river basin?
4. Does the method use conceptual models or concept maps?
5. Does the method provide guidance on how to identify leverage points?
6. If no, are there entry points to consider leverage points more explicitly?
7. Which elements are most difficult to consider and why?

3 Reference – An ontology for a basic justice assessment

Within scientific, policy, and public spheres, concerns over justice and fairness are increasingly central to discussions and debates about many of the key sustainability challenges of the 21st century (Newell and Mulvaney 2013, Leach et al. 2015, Köhler et al. 2019). From critical attention to the environmental justice dimensions of development processes and resource governance to ever more urgent concern over the inter-regional and inter-generational injustices of climate change to broad-based claims for more just distribution of wealth and provisioning of social services to meet basic human needs, justice is increasingly viewed as a fundamental component of sustainable futures. This explicit and vital attention to justice, however, requires analytical approaches capable of teasing out—and at times navigating—the complicated and often-conflicted claims and expectations around justice of diverse stakeholders in various contexts and in relation to specific system-level problems and processes. As a set of approaches centrally focused on bringing diverse societal perspectives into dialogue, co-production methods have important potential to provide a means of identifying and engaging with contested justice issues, either explicitly through guiding questions or implicitly through ex-post analysis of whatever governance issue is at stake. In this toolbox, we explore in theory the feasibility and potential value of using the co-production methods described to identify, and in some cases assess, important dimensions of different kinds of justice in either implicit or explicit ways.

Justice in its broadest sense settles what is to "each their due". In an applied context, particularly one where knowledge should be co-produced, the main concern of the researcher is not to provide normative judgements, but rather to explore, or help guide the exploration of, what different stakeholders themselves consider to be just and unjust. In research on sustainable development, two perspectives are frequently considered, what philosophers call substantive and procedural justice. Substantive justice, also termed distributive justice, refers to "the justice of the final allocation of benefits and burdens of various kinds to people" (Miller, 2021), reflecting a focus on the distribution of outcomes. Procedural justice, alternatively, refers to "the justice of the procedures that might be used to determine how benefits and burdens of various kinds are allocated to people" (Miller 2021), thus focusing on issues of access and inclusion in decision-making and governance processes. At the food-water-biodiversity nexus, procedural justice might include concerns over access to knowledge and skills that enable active participation in nature conservation or ensuring sufficiently inclusive participation opportunities in public planning processes. Substantive or distributive justice issues that might emerge include differential or unfair distribution of the negative effects of biodiversity loss, declining crop yields, or water scarcity and the resulting impacts to the water access or food security of stakeholders. Procedural and distributive justice are often linked, if not overlapping, though egalitarians point out that just procedures alone are not sufficient to ensure just outcomes. In applied research on sustainable development, both kinds of justice are frequently relevant, and it is thus worth trying to evaluate governance processes from both perspectives. The ontology of justice assessment could provide such a back-drop Johannesson et al. (2022).

Knowledge co-production as a normative concept, includes several aspirations that intersect with ideas of justice, particularly through ideas of inclusion and equal partnerships. To explore differentiated perspectives on justice in applied cases, we propose the use of a complementary reference framework to actively encourage the consideration of fundamental elements in a justice assessment.[1] The ontology of justice assessment of Johannesson et al. (2022) provides one such reference framework that may be useful.

Johannesson et al. (2022) propose that "justice is modelled as a quality inherent in a value assessment." This implies that justice is an issue in any situation where heterogeneous actors frame and attempt to solve governance challenges, i.e., in any co-production process. Thus, it should be possible to analyze any co-production process with justice in mind.

The most fundamental elements in any justice assessment as shown in Figure 2, include a *justice assessor*, a justice assessment, a justice object, a justice recipient, and shapes of justice (also known as justice principles). A justice assessor can be an individual, or a group, who perform a *justice assessment*. A *justice object,* can be just or unjust, this can be another actor, or an action itself, rules, or some state-

[1] „ the study of the most general features of what there is, and how the things there are relate to each other in the metaphysically most general ways,…" Hofweber, Thomas, "Logic and Ontology", The Stanford Encyclopedia of Philosophy (Spring 2021 Edition), Edward N. Zalta (ed.), URL = <https://plato.stanford.edu/archives/spr2021/entries/logic-ontology/>.

of-affairs. The *justice recipient* requires consideration in an assessment. This is the entity (individual, groups of individuals, animate organisms, and inanimate beings, that justice/or injustice is done to. Finally, the *justice assessor*, bases their assessment on a *justice principle*. As shown in Figure 2, justice may take many shapes or patterns, such as focusing on processes vis a vis outcomes. The justice object determines some fundamental distinctions with respect to justice principles, in that it distinguishes between procedural and substantive justice. Thus, if we look at a co-production event from a procedural justice perspective, the justice assessor can be anyone inside or outside the process, judging the rules of how participants were identified and involved. However, depending on the topic at stake in the co-production event, the participants are assessors and determine any other aspect of the justice assessment, i.e., the object, recipient and the forms of justice they value.

Based on this brief discussion of justice, the structure of justice assessments, and co-production methods, there are two broad ways in which the following methods review can consider justice:

1) The procedural and distributive justice aspects of the co-production methods itself.
    i. Is participant selection and inclusion an explicit element of the method, and if so how?
    ii. If the method design does not consider participant selection, do we know of examples where this method has been applied with a particular focus on the fair access to the process?
    iii. Is the distribution of results considered explicitly as part of the method, and if so how?
    iv. If the method design does not consider the distribution of results, do we know of examples where this method has been applied with a particular focus on the fair distribution of results?

2) The procedural and distributive justice aspects of the topics at stake?
    i. Can the method be used to assess justice in a specific governance setting?
    ii. Are there design features that relate to the ontology of justice assessments (e.g. spatial distributions might become evident in a GIS based mapping exercise, explicit roles such as justice assessor, justice recipient, identified in a role play)?
    iii. What would it need to use the method for justice assessment?
    iv. Do we know of methods that have explicitly considered justice aspects in a co-production setting? If yes, which and how?

For many applied analyses of justice, a more advanced ontology might be necessary, potentially incorporating specific forms or patterns of justice, and further context. However, in a co-production setting, it seems, such details should not be pre-determined, but should be co-produced by all the participants in the process. Therefore, further details might bias the process.

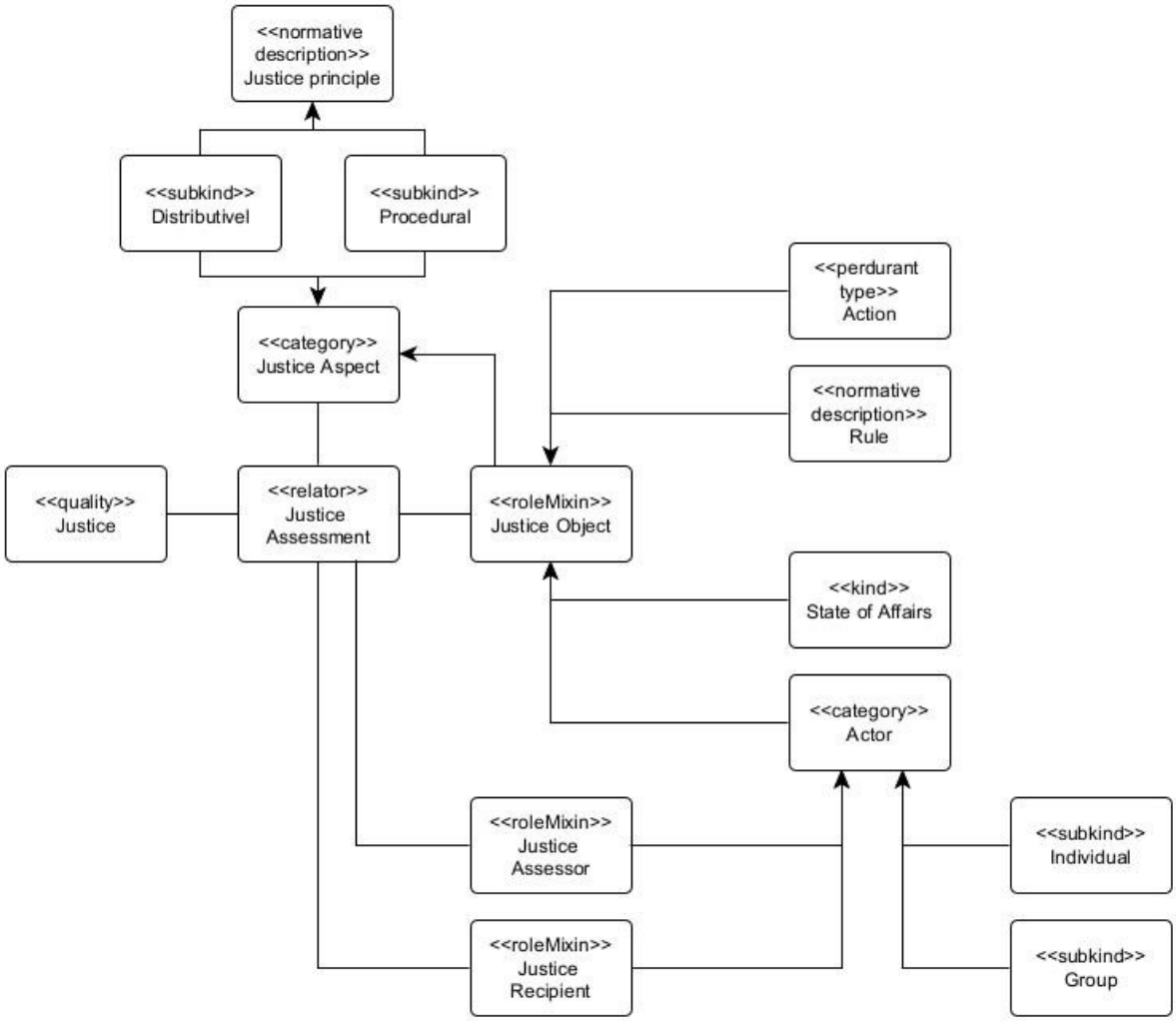

Figure 2: Fundamental elements of a justice assessment. Adapted from: Johannesson et al. 2022

4 Tools – Methods for co-production

4.1 Rich picture

Essential features

The Rich Picture (RP) approach enables a comprehensive understanding of a problem situation. With a minimum amount of guidance and as little text as possible, it invites a visualization of the diverse dimensions of a problem situation, including particular attention to soft aspects such as values and attitudes and hidden concerns. The process can be executed in less than an hour and provides a great entry point for co-production workshops and baseline for further exercises.

The method is best suited for early stages of a transdisciplinary (TD) process including problem definition, finding a joint language to describe issues, and invite the largest possible diversity of perspectives and views. However, RP can also be used punctually at different project stages, but always requires a facilitated group set-up and sufficient opportunity for discussion. Its main strengths are ease of use, and effectiveness in generating a common entry point for heterogeneous stakeholders.

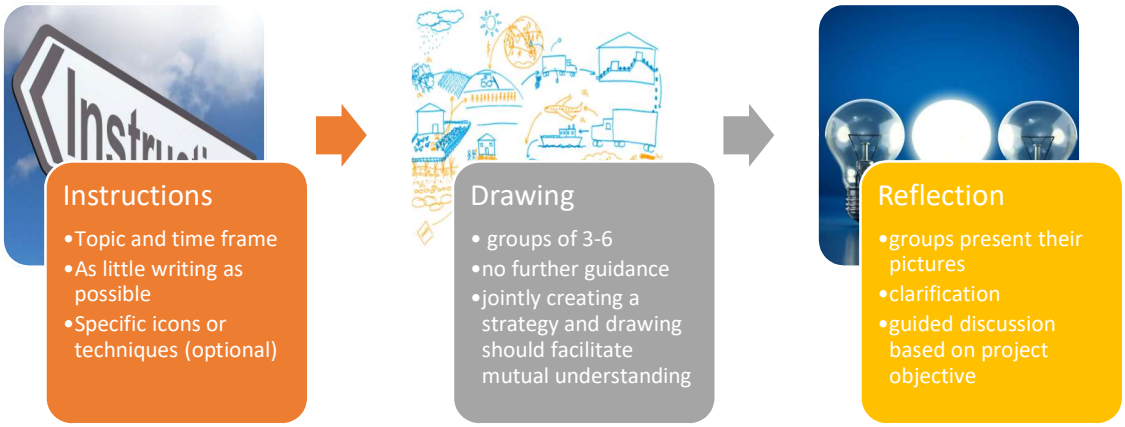

Figure 3: The three main steps for a rich picture exercise. Own design

Origin

The idea for RPs has largely developed in the context of Checkland's Soft Systems Methodology (SSM). The method appeared only in later versions of SSM, inititally as an individual analysis technique and intermediate project outcome, rather than a participatory and communications approach (Bronte-Steward 1999). Diverse disciplines and fields use RPs including information systems science, medicine and health sciences, sustainability science, and education.

Application (including at IIASA)

RPs can be used as part of a comprehensive SSM, but also as standalone tools for communication and generating shared understanding. This means they can be used as analytical tools, but also as co-production methods.

At IIASA, we have used RPs as the latter. More specifically, we have employed RPs as tools for problem definition and for creating a joint problem understanding early on in workshops (for example, we used RP to develop indicators for sustainable agriculture as part of the SAM project). In such a setting, not much time is available, but a minimum of one hour is required. In this time, participant briefing, drawing, and discussion are possible. The purpose in the SAM project was to create a joint understanding of what sustainable agriculture means for Austria, and to identify some relevant indicators. It set the stage for further targeted discussion in a fashion that participants saw most relevant.

Table 1: Rich Picture, practical aspects.

Support material	○ Simple
Stakeholder management process	○ Not specified
Min. time	Several months (incl. game design)
Min. stakeholder events	1
Min. and max. # of stakeholders	4x 3-5
Min number of facilitators	1
Facilitation skills needed	○ Intermediate
Type of outcome	○ Flexible
Approach has been used in combination with a quantitative model	○ No

Systems thinking and Rich Pictures

RP exercises are a tool primarily used to explore alternative problem framings, and thus RPs can be used to gain insight into perceived system purpose and boundaries. In line with the design and purpose of SSM, the RP method implies many systems thinking components, primarily considering systems structure, negotiating boundaries, and considering systems at different scales. The method does not, however,explicitly emphasize thinking about systems structure nor does it provide clear instructions as to how to reconcile different problem framings or system understandings. RPs are also not designed to consider dynamic behavior or identify leverage points. Nevertheless, in our experience, participants more often than not draw causal relationships and even feedback without any explicit instruction to do so.

The level of detail of guidance on RP construction varies widely, and there is no agreement on many aspects, including on whether it is important or detrimental (as in too restrictive) to the process to provide boundaries for the visualization process, or whether there should be a key for symbols to be used. In our experience, the picture often emerge as concept maps using symbols instead of words.

Table 2: Rich Picture and systems thinking.

System purpose and boundaries	○ Yes
Causal relationships and feedback	○ Potentially
Dynamic behavior	○ Potentially
Conceptual models and concept maps	○ Potentially
Leverage points	○ No

Justice and Rich Pictures

RPs focus on broad topics, inviting participants to share their views of a particular situation or system. This means that discussions of issues involving justice are not explicitly encouraged but may emerge. However, the design of this method allows room to explore aspects of justice, particularly those components included in the justice assessment ontology, as these can easily be represented in an RP. The justice assessors would be most likely the participants, who may for example visualize actors included or excluded from processes under discussion, e.g., vulnerable stakeholders. And items that are unequally distributed, such as land, or money, or access to education. Targeted follow-up questions during the discussion stage could clarify any implied notions of justice. The method may thus be useful to identify justice issues and import elements of justice assessments. For a more detailed exploration, additional and more elaborate (co-production or other) methods would be needed. We are not aware of an explicit application of RP to a justice question.

RP approaches are not by definition co-production methods. Neither the diversity of participants nor the reflection on and distribution of insights are integral to the method itself. As it is a compact method that can be integrated in larger designs, the overall project and process choices may be more aware of these issues. The design of the process is, however, very open to integrating diverse viewpoints and encouraging discussion among participants, so it has good potential to facilitate and enhance procedurally just implementation. Moreover, the fact that pictures are shared and discussed among all participants enables at least a transparent baseline for further work.

Table 3: Rich picture and justice.

Participant selection	○ no
Distribution of results	○ no
Justice in context	○ yes
Distributions explicit	○ potentially
Distributive principles	○ no

4.2 Participatory System Dynamics

Essential features

The Participatory Systems Dynamics (PSD) approach focuses on participatory framing and visualizing dynamic problems through the creation of systems diagrams, often Causal Loop Diagrams. Thus, the elements of a system, their causal relationships, and dynamic behavior (feedbacks) are used to illustrate complex problems. PSD approaches can be used with small or large groups of participants (in the realm of small n), but are typically most productive in groups of 4-6 people. Larger events can benefit from the use of smaller break out groups, but sufficient facilitation capacity is an important consideration in such settings.

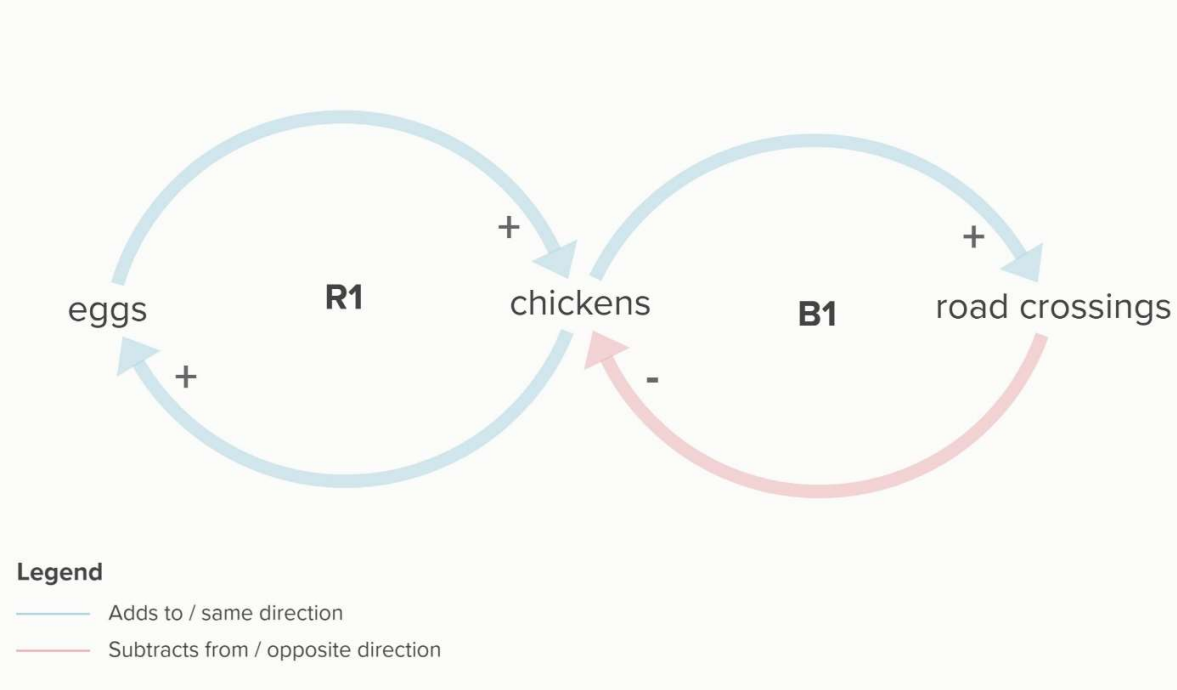

Figure 4: The chicken and egg problem, and classic intro to Causal Loop Diagram (CLD) basics. R indicates a reinforcing loop, in which the sum of connections indicates the same effect. B indicates a balancing feedback loop, where the sum of connections indicates an opposite effect.

Participatory System Dynamics (PSD) contains three sub-approaches: Group Model Building (GMB), Participatory System Dynamics Modelling (PSDM), and Community-based System Dynamics (CBSD); all of these approaches use Causal Loop or Stock and Flow Diagrams, and involve stakeholders, experts, or policy makers at various stages of a qualitative modelling process. These methods all require substantial facilitation and experience. These approaches encourage people to express and share their mental models. The critical examination of these mental models creates an effective team learning process, which allows for a shared and better understanding of the problem (Vennix 1996).

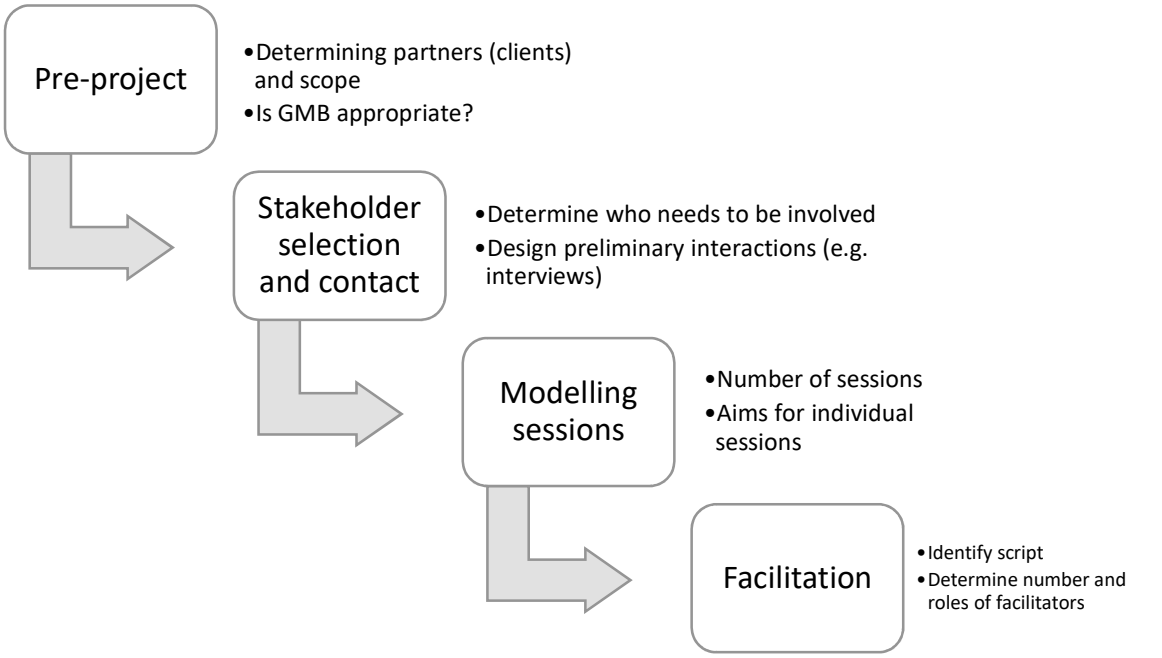

Figure 5: Group Model Building (GMB) preparation process. The modelling sessions need to cover at least problem framing and identifying a problem variable, based on which causes, consequences, and finally feedback loops can be added. Finally, dynamic behavior over time can be discussed.

Origin

PSD approaches, as the name indicates, evolved as part of Systems Dynamics (SD). Forrester, highlighted the importance of participation and the elicitation of mental models from so-called problem owners for SD as early as the 1970s (Lane 2010). GMB goes back farthest and emerged in the context of organizational problem structuring and solving (Király and Miskolczi 2019). Participatory, and specifically transdisciplinary, uses have evolved considerably with new insights, growing communities of practice, and demand (see for example Vennix 1996, Stave et al 2010).

Application (including at IIASA)

PSD approaches have been applied across a wide variety of disciplines. Indeed, SD is a peculiar area of study whose adherents are characterized by their common methodological commitment rather than by a shared disciplinary background (Királi and Miskolczki 2019). At IIASA, we have experts in several programs. Sibel Eker from ASA, for example, developed a simulation model based on three GMB workshops focused on the challenges emerging at the intersection of housing, energy and wellbeing outcomes (Eker et al. 2018). Gerid Hager, also from ASA, used a GMB process to engage with smallholder farmers to critically evaluate food security strategies (Kopainsky et al. 2017). In the POPJUS Program, Susanne Hanger-Kopp currently explores and integrates elements of PSD in a tool for knowledge integration across a variety of data sources as part of the TD research project WaterStressAT.

Table 4: PSD, practical aspects.

Support material	○ Simple
Stakeholder management process	○ Elementary
Min. time	Several days
Min. stakeholder events	2
Min. and max. # of stakeholders	3-15
Min number of facilitators	2+1 per breakout group
Facilitation skills needed	○ Advanced
Type of outcome	○ System diagram
Approach has been used in combination with a quantitative model	○ Yes

Systems analysis and Participatory SD

PSD approaches are the most direct manifestation of co-production as it emerged from early systems science and cybernetics (Vennix 1996, Kopainski et al. 2017). PSD is fundamentally a systems approach and makes explicit use of all elements of our systems analysis or systems thinking reference framework. Problem framing is an explicit step at the beginning of the process; and building the system using CLDs is the key effort of a GMB, considering dynamic behavior is envisioned as part of the process when time permits. The same goes for concept models. Identifying leverage points would require a potentially substantial add-on at the end of the process and necessitate a substantial amount of additional preparation.

Table 5: PSD and systems thinking.

System purpose and boundaries	○ Yes
Causal relationships and feedback	○ Yes
Dynamic behavior	○ Yes
Conceptual models and concept maps	○ Potentially
Leverage points	○ Potentially

Justice and Participatory SD

PSD approaches, similar to other co-production methods, have been hailed as instruments of social justice (e.g. Hovmand 2014). Indeed, the GMB process features a pre-phase for selecting and contacting stakeholders, which can be used to support a just selection process. Facilitation plays an important role in PSD, and thus facilitation preparation and training focused on incorporating justice concerns and

dimensions into the workshop sessions can help support a fair process. The distribution of outcomes as designed with GMB is not well suited to serve as a justice enhancing method, as GMB is designed for a client. A community-based SD process on the other hand might be better suited to this end, as it is designed to serve a community, i.e., by definition a wider audience.

CLDs, as a central tool to PSD, do not explicitly consider actors, which may make justice assessment more complicated, or at least require specific training in designing CLDs in a way that make concerns of distributive justice visible. The framing stage would be a crucial opportunity to identify some of the fundamental aspects of justice assessment, including who is the assessor and what is the object.

PSD has been used to investigate dimensions of justice in some contexts; for example, stakeholder identification of determinants of inequity in healthy eating (Friel et al. 2017). Other SD studies explicitly address justice questions but are most often not participatory. However, this implies that CLDs could be suitable to visualize justice also in PSD. We are not aware of any meta studies on how PSD and justice considerations can be linked.

Table 6: PSD and justice.

Participant selection	○ yes
Distribution of results	○ no
Justice in context	○ potentially
Distributions explicit	○ potentially
Distributive principles	○ no

4.3 Serious games

Essential features

Serious games are a participatory process where participants collectively explore a complex reality and complex challenges such as those encountered in sustainable development and climate risk management (CRM). Serious games fictionally recreate a specific governance setting involving several heterogeneous stakeholder groups. These simulated real-world environments enable experiential learning about interactions between multiple stakeholders with conflicting agendas, problem frames and worldviews. In a serious game, these diverse stakeholders discuss and negotiate alternative policy solutions and their tradeoffs. They thus unravel stakeholder dynamics and tease out behavioral pitfalls that may prevent the effective collaboration, coordination, and collective action necessary for the governance of complex problems. Serious games can range from a simple boardgame setup to complex desktop or online interfaces. There are several steps in a serious game application (Figure 6). The steps below are iterative, e.g., step 3-4 can be repeated several times before moving to step 5.

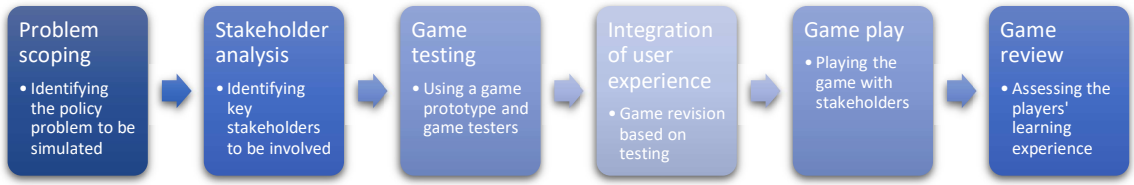

Figure 6: General and simplified steps of a serious game development and application (Adapted from: Urgo et al., 2022)

Origin

Application (including at IIASA)

Serious games have proven to be unique learning tools in a wide range of participatory settings, supporting the exploration and understanding of essential governance issues. Their value is increasingly recognized for informing and guiding governance in complex settings, for instance in climate risk management (CRM) (Parson, 1997; Mayer, 2009; Haug et al., 2011; Abad et al., 2020).

At IIASA, several groups feature expertise in social and policy simulations in general and serious games more specifically, particularly Water Security, Equity and Justice, and the Systemic Risk and Resilience research groups. The type of serious game used by these groups varies greatly in scope, aims and format. We outline two examples of serious games developed at IIASA below. The PHUSICOS simulation is a role-playing exercise in which nature-based solutions are decided on and funded. The Climate Migration Policy Simulation is coupled to an agent-based model and aims to simulate the economic consequences of migration in different scenarios.

The PHUSICOS simulation represents a fictional setting (PHUSICOS town) at risk from extreme events and in which different stakeholder groups are represented. It was developed under the H2020-funded project PHUSICOS and aims to simulate the complex governance setting in which stakeholders with various interests and often-opposing worldviews and goals make decisions on and implement nature-based solutions (NBS). The simulation is inspired by real-world PHUSICOS research sites and their governance

settings and challenges. The game is relevant to all those working on and implementing NBS, particularly practitioners and authorities, as it simulates the NBS implementation decision-making process. The game is designed for approximately 7-40 players.

In the game, players have the opportunity to prioritize problems, plan and implement solutions, and solve conflicts via negotiations and dialogue. Together, they creatively experiment and test various risk reduction solutions. The game thus sets emphasis on stakeholders' negotiations regarding the implementation of different options for reducing disaster risk and assessing their co-benefits and trade-offs.

Figure 7: The PHUSICOS simulation game interface (Source: CRS, 2021)

The Climate Migration Policy Simulation addresses important, yet difficult, questions concerning immigration to Austria. It is based on a hypothetical but potentially realistic narrative scenario for the near future when the European Union and Austria may experience a (second) migration crisis. A particular focus is on 'environmental' migrants who are fleeing economic or ecological conditions worsened by climate change. An agent-based model that provides insights into the economic consequences of the migration scenario supports the exercise. Participants take on roles of Austrian political party representatives who discuss policy proposals that would later shape the country's response to the problem of environmental or climate immigration. The policy exercise is designed to address adversity by including diverse worldviews as one of the critical factors guiding the political debate. The participants can argue for potentially conflicting policy positions and prescriptions such as the status of environmental migrants, financial support for MENA countries, and participation in the Mediterranean rescue effort. The exercise enables these different views, or cultural discourses, to be represented, critically reflected upon, and (ideally) respected. At the center of the simulation is a negotiation process that takes place in a virtual 'conference center' with multiple conference rooms, enabling both multilateral and bilateral negotiations of the specific policy questions. Participants express their preferences via voting and receive feedback (based on their choices) represented through stylized media headlines. Using this kind of setting creates a familiar environment for the participants, similar to what they know from real conference and consultation events.

Table 7: Serious games, practical aspects.

Support material	○ Elaborate
Stakeholder management process	○ Not specified
Min. time	Several months (incl. game design)
Min. stakeholder events	1 2-3 (co-production)
Min. and max. # of stakeholders	3 3-5 x 4-6 (co-production)
Min number of facilitators	1+1 per breakout group
Facilitation skills needed	○ Intermediate-Advanced
Type of outcome	○ Social learning
Approach has been used in combination with a quantitative model	○ Yes

Systems analysis and serious games

Social simulations – as their name suggests - aim to represent a social system as a whole. They therefore partially emerged to map complex systems. Indeed, social simulations amongst others emerged to complement traditional, purely mathematical simulations (Troitzsch, 1997) by introducing a social or 'real life' dimension to these models.

Table 8: Serious games and systems analysis.

System purpose and boundaries	○ Yes
Causal relationships and feedback	○ Potentially
Dynamic behavior	○ Potentially
Conceptual models and concept maps	○ n.a.
Leverage points	○ Potentially

Justice and serious games

By allowing stakeholders to discuss, negotiate and co-create different solutions for a given context, social simulations have the potential to capture different worldviews, values, tradeoffs and priorities. They can thus be used as methods for increasing procedural justice (by engaging a variety of stakeholders and eliciting their views). Depending on their design and primary aims, they can also help assess distributive justice directly by helping to identify who benefits or loses out in alternative simulated scenarios.

Table 9: Serious games and justice.

Participant selection	○ no
Distribution of results	○ no
Justice in context	○ potentially
Distributions explicit	○ potentially
Distributive principles	○ potentially

4.4 Role-play

Essential features

Role-plays are "as-if" experiments, in which participants are asked to take the role of a particular person in a particular situation and behave "as if" they were that person (Hendrick & Jones, 1972; Van Ments, 1983; Wakefield et al., 2012). Players, by assuming the roles of other actors, distance themselves from their own personal beliefs and develop a reciprocal understanding and acceptance of the interests and resources of their co-players (Geurts et al., 2007). Moreover, temporarily freed from everyday limitations, players become more open and creative, often entering into meaningful discussions and coming up with innovative solutions to the in-game problems (Solinska-Nowak et al., 2018). Based on our own effectiveness assessment, we found a role-play to have a high potential for fostering social learning (Schinko and Bednar-Friedl 2022).

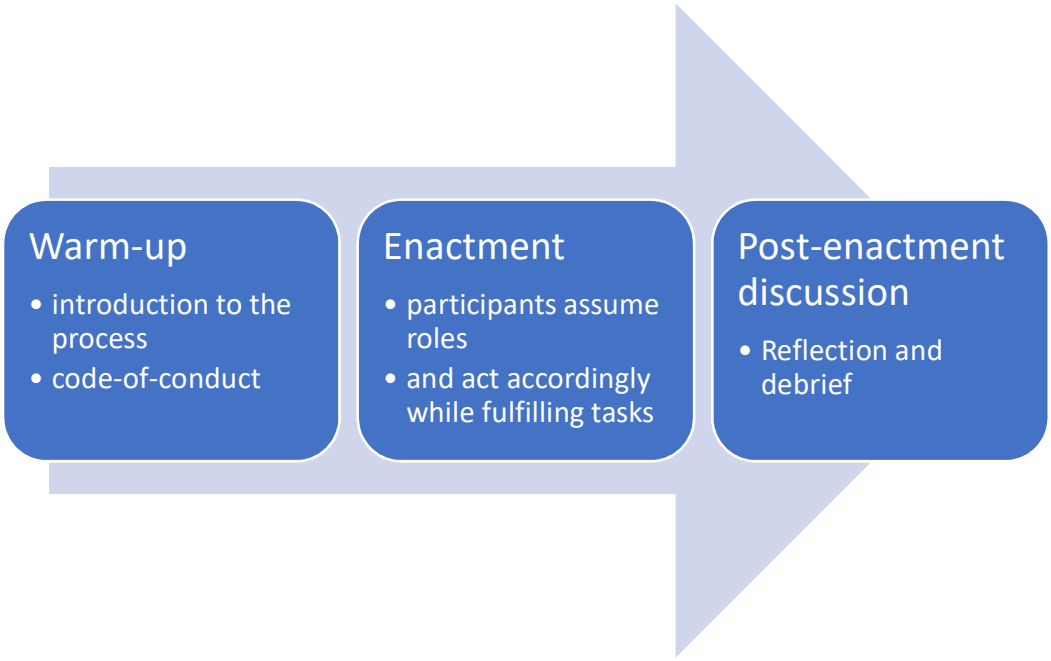

Figure 7: Three functional phases of role-play according to Wohlking and Gill 1980.

Application (including at IIASA)

Role-playing is historically linked with acting and drama. In the 20th century, role-play gained importance as a therapeutic procedure in psychotherapy, in business training and education (O'Sullivan, 2011). Role-play has found its way into sustainability science mostly by means of more elaborate methods such as serious games. Role-plays have been shown to be useful in cultivating climate change adaptation literacy, enhancing collaborative capacity and facilitating social learning; as such they could be useful in the education of professionals in a range of sustainability-related fields (Rumore 2016).

The RESPECT role-play simulation in the context of managing climate-related risks

The key objective of the role-play simulation in Lienz was to draw on social learning theory (Pahl-Wostl and Hare, 2004; Reed et al., 2010) to formulate an aligned understanding of how local risks, roles, and possible actions might be defined and shared among multiple societal actors. The project featured a co-design process which comprised a literature/media review and semi-structured key-informant interviews. This preparatory work resulted in the selection of riverine-flood risk, the most pressing climate-related risk in the case-study region, for the role-play simulation. In a next step, we worked with key stakeholders in the region to identify a broad list of potential flood risk management measures as a basis for jointly designing risk management portfolios in the role-play simulation.

The RESPECT role-play concept (Lintschnig et al., 2019) uses possible climate risk scenarios to identify a portfolio of feasible risk management measures according to different layers of risk. Risk layering involves the identification of efficient and acceptable interventions based on the recurrence of hazards and the allocation of roles and responsibilities to reduce, finance, or accept risks. The future risk scenarios are integrated into the RESPECT roleplay concept in the form of storylines co-developed with key stakeholders in the study region and building on the region's most recent climate and socioeconomic data. Storylines provide narrative descriptions of plausible pathways that lead to the development of future climate-related risks. The RESPECT role-play concept requires players to work out the responsibilities of public- and private-sector actors with respect to different climate risk management measures provided to the participants in the form of a descriptive catalog. They then need to elaborate from the perspective of their respective role-play character as characterized by the distributed role cards upon the effectiveness of the adaptation measures for two contrasting risk categories that differ in their return period and in the level of stress imposed by risk (risk-layering).

The RESPECT role-play simulation highlights the merit of collaborative research approaches as follows (Schinko and Bednar-Friedl, 2022):

i) they enable diverse societal stakeholders (policy makers, decisionmakers, civil society, private sector, households, researchers) to better understand the interacting dimensions of flood risk as well as each other's risk perceptions, interests, and needs in addressing this climate-related risk;

ii) they engage societal stakeholders beyond traditional policy and decision-making communities in informed and inclusive public discussion and debate around challenges of, and solutions to, managing flood risk; and

iii) they have the potential to support the breaking down of cultural, political, and institutional barriers, enabling more inclusive, reflexive, and transformative stakeholder processes.

Table 10: Role-play, practical aspects.

Support material	○ Simple
Stakeholder management process	○ Not specified
Min. time	4-6h
Min. stakeholder events	1
Min. and max. # of stakeholders	[enter lower and upper bound]
Min number of facilitators	[enter number]
Facilitation skills needed	○ Advanced
Type of outcome	○ N.a.
Approach has been used in combination with a quantitative model	○ No

Systems analysis and Role-play

Role-play simulations are qualitative tools for system analysis as they work with a diverse set of stakeholders on complex problems, thus generating and layering alternative views of societal systems. They do work with pre-defined boundaries as problem and roles have been defined ahead of the exercise, however causal relationships and feedbacks are indeed essential in the discussion although not necessarily recorded as such, which would require additional efforts. Dynamic behavior may be implied, but is difficult to capture, unless a specific task is included in the play; this also goes for the use of conceptual models and concept maps. All elements of systems thinking may be a topic in the post-enactment phase, but also this is not pre-determined by the original method.

Table 11: Role-play and systems analysis.

System purpose and boundaries	○ No
Causal relationships and feedback	○ Yes
Dynamic behavior	○ Potentially
Conceptual models and concept maps	○ Potentially
Leverage points	○ Potentially

Justice and Role-play

Given the character of role-plays, where participants take on the roles of others in a socio-political system, justice, even if not the main topic, is a strong underlying current in most topics that cross sectors and spheres of influence and are strongly infused with power dynamics. It is well suited to explore justice in context, most importantly procedural justice and potentially certain distributional aspects. For example, players in the game may claim insufficient inclusion of their persona in planning processes, and discussions might unfold as to why such a situation came to be through other players justifying the actions of other roles represented in the game. The same goes for perceptions of (un)fair distributive outcomes of policies, e.g. access to funding instruments for renewable installations, or zoning decision putting certain land owners at a disadvantages.

Table 12: Role-play and justice.

Participant selection	○ no
Distribution of results	○ no
Justice in context	○ yes
Distributions explicit	○ yes
Distributive principles	○ no

4.5 Participatory GIS (PGIS)

Essential Features

Participatory Geographical Information Systems (PGIS) - sometimes also only referred to as 'participatory mapping' - are a data gathering method in which local stakeholders locate features of interest on analog or digital maps. These spatial details can then be digitized through geospatial information management tools, most commonly in a Geographic information System (GIS) but also in sketch maps, 3-dimensional models, aerial photographs, or satellite imagery (Rambaldi et al., 2006). However, maps can also remain analog. This means that PGIS can range from very simple mapping exercises, such as drawings on the ground, to very technologically advanced mapping, such as remote sensing. PGIS methods have increasingly emerged in the field of ecosystem service valuation, in particular to map cultural services traditionally less well represented in ecosystem services assessments (Brown & Fagerholm, 2015).

Traditional and indigenous knowledge have often been neglected in global efforts to map environmental features and variables. PGIS allows local and traditional data and knowledge on socio-ecological systems and other less tangible values, such as places of cultural importance, to be captured and become more visible. It also promotes the empowerment of stakeholders, community groups and individual citizens who might otherwise be excluded from environmental planning processes (Zeballos-Velarde, 2021). PGIS thus facilitates collaborative planning. It initially emerged as a tool to empower local communities by giving them a voice in spatial planning decisions. However, as with any participatory process, PGIS maps can only be considered co-produced if all relevant stakeholders have been engaged in an equal and

meaningful way, this means going beyond traditionally used data collection methods such as interviews and surveys.

There are five key steps in PGIS (Figure 8), which can be iterative to revise a map once it has been created.

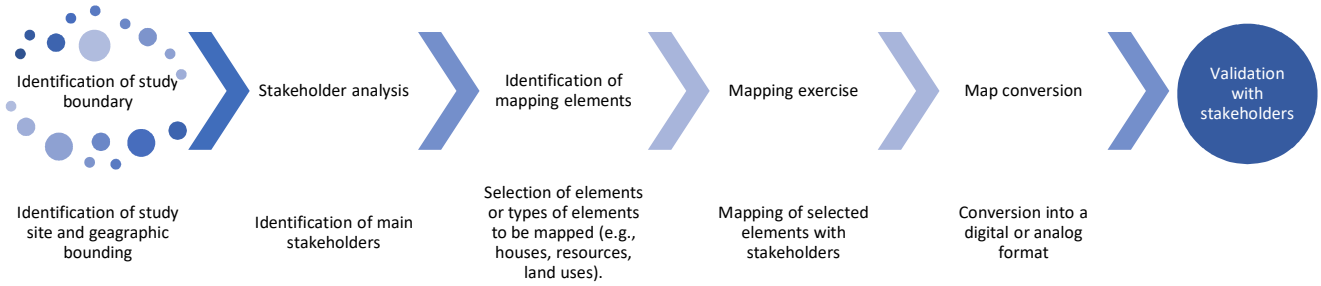

Figure 8: PGIS process. (Adapted from: Sulistyawan et al., 2018)

Origin

Maps made by communities to capture boundaries and resources have existed for a very long time – from cave drawings to lines in the sand (Cochrane et al., 2014). The term 'participatory mapping' first emerged after the 2nd World War and as a response to criticism of top-down cartographic practices in which local communities were excluded from decision-making. In particular, participatory mapping was meant to help empower indigenous populations by mapping their territories. Specifically, one of the most known examples of early participatory maps were produced in the 1980 by the Cree tribes of Canada to produce court-ready maps to protect their land from developers (Guldi, 2017). PGIS therefore takes its roots in urban and spatial planning.

As GIS technologies became more affordable in the 1990s, this gave rise to PGIS (Bryan, 2015). PGIS emerged as a term of its own right in 1996, at a meeting of the National Center for Geographic Information and Analysis (ibid).

Table 13: PGIS practical aspects.

Support material	○ Simple

Stakeholder management process	○ Elementary
Min. time	4-6h
Min. stakeholder events	1 2 (co-production)
Min. and max. # of stakeholders	2 3-5 x 4-6 (co-production)
Min number of facilitators	1+1 per breakout group
Facilitation skills needed	○ Intermediate
Type of outcome	○ Map
Approach has been used in combination with a quantitative model	○ Yes

Applications (including at IIASA)

The NERC-funded Landslide EVO Project focused on Nepal's mountainous communities, which are vulnerable to multiple hazards including landslides and floods. In Nepal's rural areas, lack of geospatial data is hampering a better understanding of natural hazards and associated risks. Additionally, communities are mostly seen as knowledge receivers, undermining the possibility of co-creating knowledge in collaborative ways. This has created a gap between researchers and communities. In 2019, PGIS approaches were used to map resources, exposure, and vulnerabilities to natural hazards with local communities in Far-West Nepal (Parajuli et al., 2020). The collected data were made freely available to community members as well as government and humanitarian actors so that they can inform development and disaster risk reduction planning in the region.

Systems analysis and PGIS

PGIS does not inherently enable systems thinking, when done comprehensively through wide engagement, PGIS can help represent complex systems by introducing local knowledge into environmental planning and decision-making. In particular, PGIS have emerged as tools that can help quantify and map the non-material benefits people obtain from ecosystems. These include intrinsic benefits, social values and cultural ecosystem services, all of which have often been underrepresented in socio-ecological systems due to their abstract nature. PGIS can therefore help mapping socio-ecological systems in a more comprehensive way.

Table 14: PGIS and systems analysis.

System purpose and boundaries	○ Potentially
Causal relationships and feedback	○ No
Dynamic behavior	○ No

Conceptual models and concept maps	○ No
Leverage points	○ No

Justice and PGIS

By definition, the mapping of different landscape features, their boundaries, resource location, or areas of jurisdiction can be very political and contentious. Agreeing on these locations and boundaries will often trigger discussions on concepts that have strong justice dimensions, such as ownership, mandate, and resource allocation. As a participatory method in which a diversity of stakeholders can map different landscape features as well as the value they attribute to them, PGIS is a powerful tool for increasing procedural justice.

PGIS also has the potential to make distributive justice issues explicit by revealing areas of local importance or economic value, but also areas of contention and conflict. PGIS can therefore help to incorporate distributive justice in spatial planning decisions by highlighting the 'losers' and 'winners' of land-based decisions. PGIS has therefore often been used to capture indigenous knowledge and local values.

Table 15: PGIS and justice.

Participant selection	○ yes
Distribution of results	○ no
Justice in context	○ yes
Distributions explicit	○ yes
Distributive principles	○ no

4.6 Design Thinking (DT)

Essential features

Design Thinking (DT) is a participatory approach that focuses on, first, understanding user-design problems related to a variety of "products" and, second, on creating and testing innovative problem solutions - these may include physical goods but also non-physical products such as services and policy instruments. As such, DT is a human-centred approach (Bloomkamp 2018; Micheli et al. 2018; Roaynor et al. 2018; Weeby 2018) to problem definition and solving, typically achieved through iterative innovation. DT can be seen as a tool for social, technical and socio-technical innovation as it aims to design solutions within set framework conditions. At its core, DT assumes that current solutions are and have proven to be inadequate and thus aims to reconfigure problem understanding as a prerequisite for innovative solution finding. The process is made up of five steps (Figure 9) that must be implemented in order to the method encourages revisiting previous project steps until a solution is found. DT's emphasis

on creativity, intuition, iteration, and adaptation distinguish it from conventional policymaking, which is "rational, logical, deductive and macro" -oriented, when applied to a governance problem (2018, p.17).

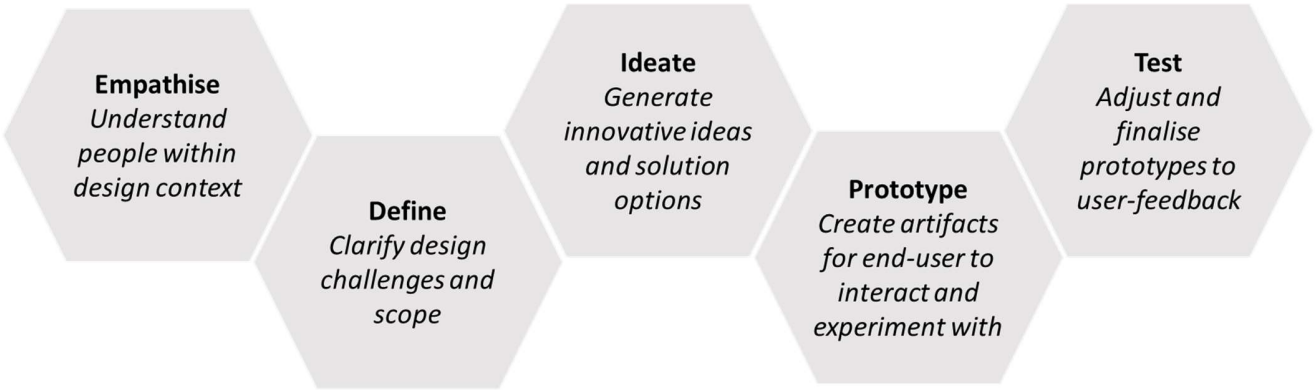

Figure 9: Five-step Design Thinking process. Source: Adopted from Institute for Design (n.d.)

DT incorporates multiple perspectives regarding the lived experiences of end-users (Brown 2008; Brown and Wyatt 2010; Mintrom and Thomas 2018) and is increasingly being used in the public sector to encourage citizen participation and user-oriented design of public policy and services (Mintrom and Luetjens 2016; Kimbell and Bailey 2017; Blomkamp 2018; Weeby 2018). In such contexts it is believed to close the many gaps that exist between "policy design, the services governments deliver, and the needs and expectations of citizens" (Mintrom and Thomas 2018, p. 312). Thus, DT offers great potential for reducing common cognitive biases of management and public policy making. These biases include most importantly projection bias – assuming the past as the basis for the future; empathy gap – projecting one's own perspectives onto others; and availability bias – overvaluing what is easily accessible (Liedtka 2015). Despite this potential, evidence of DT's effects remains largely anecdotal and there is a dearth of research evaluating the impact of DT in the context of public sector issues (Liedtka 2018).

Although DT does not involve co-production by definition, the process can easily be adapted to enable co-production while maintaining all the benefits of the method (see application).

Origin

DT emerged from the field of design studies in the early 1990s and was later integrated as a concept in management and business studies in 2009, most prominently by Roger Martin who highlights the benefits of design thinking for breakthrough innovation. DT has further evolved as a method to address complex problems through explorative deliberation of problem sources (Johansson-Sköldberg, et al. 2013). Arguably, the most used DT framework is that proposed by Stanford Design School and comprises the five steps also used in our approach described above.

Applications (including at IIASA)

At IIASA EQU has explored Design Thinking in the coDesign project. Future ambitions are to explore how DT may help overcome path dependencies in climate risk governance.

In the coDesign project we worked with two climate and energy model regions (KEM Baden and KEM Freistadt). Our aim was to determine the root causes and possible solutions for the implementation gap, which exists in the Austrian energy transition between goal setting at the national level and the local implementation. For this purpose, we adapted a typical DT process to enable co-production. This required carefully selecting diverse stakeholders to participate in the project. We mapped stakeholders based on publicly available documentation of the KEM region and local media. KEM managers reviewed, adapted and confirmed the maps. Based on these maps we interviewed relevant stakeholders at the national, federal and local levels for each KEM. The interviews were semi-structured and elicited perceptions and experiences regarding the challenges of implementing energy transition measures as well as determining institutional framework conditions, which may facilitate or deter successful implementation (see Irshaid et al., 2021). Based on the interviews and further consultation with local partners, key challenges specific to each region were identified to be further examined in the DT processes. This process entailed a DT workshop in the KEM Baden, focused on *ecologizing* spatial heating in Baden, and one DT workshop in the KEM Freistadt, focused on identifying and solving problems within the OurPower energy trading platform.

Activities within the DT workshops included:

- Creating journey maps of specific problems where participants were asked to backcast on problems and define pivotal points in problem identification (i.e., customer journeys)
- Serious play (using LEGO or Flip charts) to recreate the setting within which the problem exists
- Participants then visited pre-selected stakeholders in the field (in the KEM Baden groups visited a a local small enterprise; in the KEM Freistadt groups visited renewable energy producers). Within this exercise groups were tasked with interviewing stakeholders to learn more about the problems and challenges.
- The “Ideate” step invited groups to create a fictional persona and design innovative and satisfactory end-user experiences. The solutions which emerged from this exercise were then prototyped.
- Prototypes were presented to the end-users (i.e., persons who were previously interviewed). Feedback was then integrated in the final design and presented.

Prior to and following the DT workshops, surveys were conducted with participants to elicit information about the effect of the DT workshops on problem understanding and innovation. The quantitative evaluation showed that the DT workshop did not result in significant changes in perceptions, probably because of the high-level motivation and abilities of the actors involved and the overall belief in the high feasibility of low-carbon transition. We observed, however, a significant change with respect to the attitude to citizens’ contribution to policy innovation.

Qualitative follow-up interviews with KEM managers conducted twice over the following year revealed that DT played a significant role in the development of the OurPower platform. In Baden, however the implementation of innovative solutions was limited by institutional and political framework conditions.

Table 16: DT and practical aspects.

Support material	○ Elaborate
Stakeholder management process	○ Elementary
Min. time	[enter number]
Min. stakeholder events	2
Min. and max. # of stakeholders	[enter number]
Min number of facilitators	1 per user group
Facilitation skills needed	○ Advanced
Type of outcome	○
Approach has been used in combination with a quantitative model	○ No

Systems analysis and Design Thinking

Within the first step of a DT process, the Empathize phase, participants are confronted with a specific problem or goal and are given a task, which facilitates the mapping of the system within which the problem exists. This serves the purpose of placing the problem within a system and actor network. In the coDesign project's Baden case study this was done by asking participants to role-play an actor seeking to change their heating system and then draw out a timeline of actions and challenges the actor would experience. Within this and the subsequent step, the Define phase, participants expand the understanding of systems and institutions within which actors operate through a personal exercise. While the knowledge verbalized and generated in these steps can be used for system mapping, systems thinking is not explicitly included.

Table 17: DT and systems thinking.

System purpose and boundaries	○ Yes
Causal relationships and feedback	○ No
Dynamic behavior	○ No
Conceptual models and concept maps	○ N.a.
Leverage points	○ N.a.

Justice and Design Thinking

DT does not inherently consider justice. Successful applications do not rely on the inclusion of all societal actor groups or fairness dimensions, specifically due to the method's application in technological innovation and the economic market sphere. Thus the inclusion of fairness and justice considerations are context dependent, that is whether justice is considered depends on the problem definition and—in the case of sustainability issues—whether justice issues are a prerequisite for a successful social innovation. This was also reflected in the DT application within the coDesign project. Through the inclusion of a variety of stakeholders and actors, as well as via the persona exercise conducted within the workshop, different values and interests were explored and included in the policy design processes. While questions of fairness and justice were not explicitly raised in this process, we did find there to be significant potential for such considerations within this approach.

Table 18: DT and justice.

Participant selection	○ no
Distribution of results	○ no
Justice in context	○ yes
Distributions explicit	○ no
Distributive principles	○ no

4.7 Plural rationality approaches (PRA)

Essential features

Plural rationality approaches (PRA) do not seek a consensus on a single best option, but rather a compromise solution reached through explicit elicitation of stakeholders' perspectives on the nature and cause of the problem and its solution (Thompson et al. 1990; Thompson 2008). PRA involve four essential steps: (i) stakeholder perspectives' elicitation and discourse identification; (ii) generation of technical-policy options; (iii) working groups to discuss the options and identify priorities for action; (iv) facilitated discussion to reach a clumsy/compromise solution.

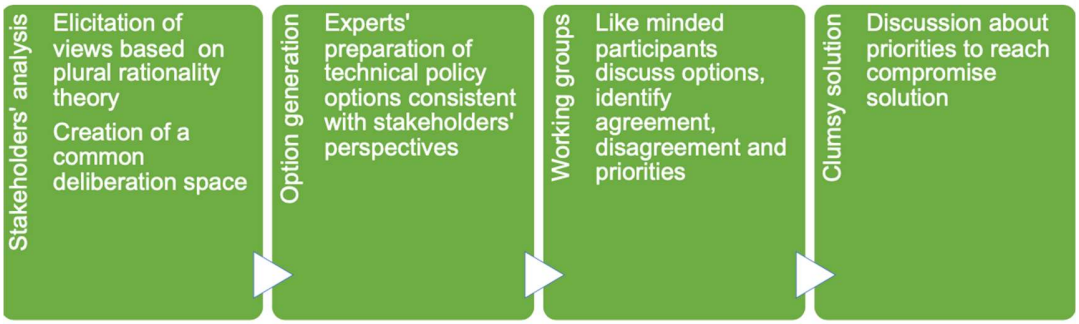

Figure 10: Illustration of key phases in plural rationality-based approaches (own elaboration).

In PRA, knowledge co-production plays a vital role because experts and stakeholders co-produce options keeping heterogeneous perspectives in mind. Experts interact with stakeholders to ensure the translation of qualitative discourses into feasible, operational and often quantitative options. A compromise/clumsy solution is achieved after discussion of shared priorities between groups supporting different options. The pre-requisites for a clumsy solution are accessibility (each perspective able to make itself heard) and responsiveness (each perspective engaged with, rather than dismissive of the others). This means that a critical point is the respect for heterogeneity of stakeholders' views rather than convergence or persuasion towards a consensus.

Origin

PRA draw upon the Theory of Plural Rationality which has demonstrated that in every policy discussion, there is a limited number of socially constructed stakeholders' perspectives: hierarchy, individualism, egalitarianism, and fatalism (ibid.). These perspectives are characterized by shared attitudes, behaviors, interests, and views on what is relevant and why for different stakeholders.

For example, the hierarchical perspective is pro-control and insists that problems demand expertly planned solutions. This translates into top-down planning through government authorities with their network of experts. The individualist voice is instead pro-market. It calls for de-regulation, for the freedom to innovate and take risks, and for the explicit recognition of trade-offs among competing uses of resources. The egalitarian perspective is strident and critical, expressing deep skepticism of both the individualist notion of trade-offs, especially when lives and other "sacred" values are at issue, and the hierarchists' claim that experts know what is best. This perspective usually argues for a more holistic, moralistic, and natural approach to problems. Finally, the fatalist perspective sees no possibility of effecting change for the better.

The perspectives can be adapted to a number of different environmental issues (e.g. climate change, natural hazards, urban sustainability) and provide a point of reference to understand the discourses to which stakeholders adhere. Discourses are shared, structured ways of speaking, thinking, interpreting, and representing ideas and set of ideas (Dryzek 1997). They can be identified through a variety of social science methods such as interviews, focus groups, questionnaire surveys, documentary analysis, cognitive mapping methods (ibid.; Thompson et al. 1998). Discourses form the basis for knowledge co-production:

technical options, scenarios, integrated assessment models, or other tools can be used to "translate" the qualitative information gained through the discourses into quantitative data/technical options used for supporting the decision-making process (Ney et al. 1997).

Applications (including at IIASA)

PRA have been applied to a variety of environmental issues such as the handling of radioactive materials, ropeways in Nepal, climate change and cities, insurance for flood risk, disaster risk management (Thompson et al. 1998; Vari et al. 2003; Verveij et al.2006). At IIASA researchers at EQU have been spearheading this kind of research and developing co-production processes building on the Theory of Plural Rationality. Mike Thompson has played a key role in the Theory and PRA development (Thompson 2008). Anna Scolobig, and Joanne Bayer, for example, have applied it in a case of landslide risk mitigation in Southern Italy (Linnerooth Bayer et al. 2016; Scolobig et al. 2016) and early warning systems in Austria (Preuner et al. 2017; Scolobig et al. 2017).

In the Safeland project, the experts involved in a participatory process played a unique role by providing technical options that corresponded to the different perspectives on landslide risk mitigation held by the stakeholders (Linnerooth Bayer et al. 2016). Three different risk mitigation options reflecting respectively the hierarchical, egalitarian, and individualistic perspectives (called Safety First, Careful stewardship of the mountains, and Rational Choice) were provided by the scientific advisors/experts based on the results of interviews with stakeholders, questionnaire surveys, and focus groups. The decision-making process involved 18 residents and occurred in a conflict-laden social context. Indeed, a few years before Safeland, a €24.5 million risk reduction project by the regional authorities was rejected by the Municipal Council. During the process, the citizens discussed their preferred option in working groups and identified priorities. The results of the working groups showed that most participants agreed on the priorities to reduce landslide risk—i.e., an integrated system to monitor landslides, stabilization of the open slopes with naturalistic engineering works, an improved warning system and maintenance of existing risk mitigation measures. Based on the results of the facilitated dialogue, experts drafted a compromise/clumsy solution. In this way, a suitable risk mitigation plan gradually moved from a contested terrain to increasing convergence on a clumsy solution (Scolobig et al. 2016). Some naturalistic engineering measures included in the plan were finalised in the year 2019 and other measures are under construction at the time of this writing.

Table 19: PRA, practical aspects.

Support material	○ Simple-elaborate
Stakeholder management process	○ Not specified
Min. time	6 months
Min. stakeholder events	3
Min. and max. # of stakeholders	n.a.
Min number of facilitators	2
Facilitation skills needed	○ Advanced

Type of outcome	○ Flexible
Approach has been used in combination with a quantitative model	○ Yes

Systems analysis and PRA

PRA can be considered system analysis especially with respect to the understanding of the perspectives of the stakeholders/ human actors in the system. This is particularly key in 'wicked' problem situations that are not clearly bounded, that have uncertain and unknown interrelationships, and that lack a well-defined and agreed problem statement (e.g. climate change). Thus, problem framing –as an element of system analysis- plays a central role in PRA. Moreover, PRA involves the accommodation of multiple alternative worldviews or interests, generating decision ownership through inclusive stakeholder participation and transparency. It facilitates deliberation through system representations of the problem space for systematic group exploration. Stakeholders' views may be represented using conceptual models or concept maps, e.g. to represent the key elements of the individualist, hierarchical, fatalist or egalitarian perspective. However, the analysis of causal relationships, leverage points and feedback loops are not a core element in PRA.

Table 20: PRA and systems analysis.

System purpose and boundaries	○ Yes
Causal relationships and feedback	○ Potentially
Dynamic behavior	○ No
Conceptual models and concept maps	○ Potentially
Leverage points	○ No

Justice and PRA

Procedural justice is at the core of PRA. Specific attention is dedicated to the discourse elicitation of stakeholders that are not always included in decision making processes, e.g. socially vulnerable/less powerful groups. Participant selection is conducted in order to guarantee that different stakeholder perspectives are equally included during the participatory processes often used to implement PRA. Distributive justice is taken into account when a compromise solution is discussed, e.g. with considerations on who benefits and who losses in relation to a possible set of actions/measures. Moreover a compromise solution is often the result of a negotiation/identification of shared priorities among groups, so it does indirectly promote a fair consideration of different values and interests. Discussion on justice issues are often explicitly encouraged by the facilitator(s). However a justice framework or assessment is not explicitly included as an element of PRA. There is certainly potential to include justice considerations more explicitly in PRA.

Table 21: PRA and justice.

Participant selection	○ yes
Distribution of results	○ yes
Justice in context	○ yes
Distributions explicit	○ potentially
Distributive principles	○ yes

4.8 Social Multi-Criteria Evaluation (SMCE)

Essential features

Multi-criteria analysis (MCA) is a formalized and well-established decision support method used to reach a consensus regarding the ranking of different alternatives. By allowing impacts to be measured in different units, MCA supports decision makers to identify the most desirable alternative.

As opposed to MCA, SMCE pays particular attention to combining stakeholder perspectives and participatory/institutional approaches to analyze stakeholder relationships and coalitions (Munda 2008; Munda et al. 1995). SMCE involves four phases (Figure 11).

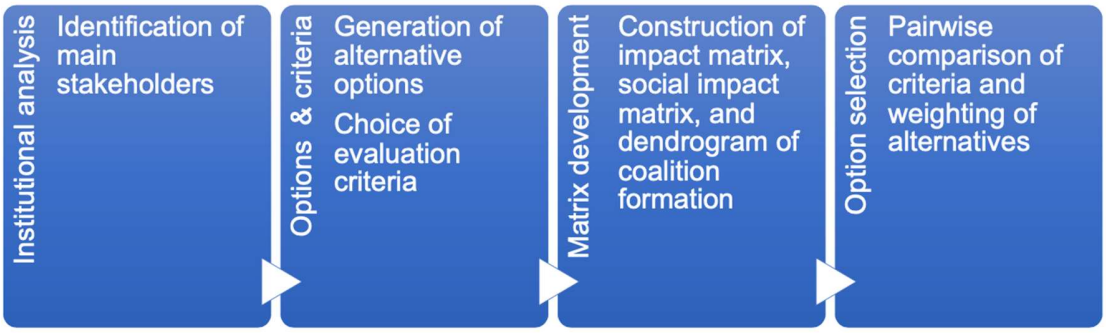

Figure 11: Key phases in Social Multi-Criteria Evaluation (own elaboration).

Phase 1 is an institutional analysis, which identifies the key stakeholders and describes their tasks, responsibilities, and views about the problem to be addressed. Phase 2 involves experts selecting alternative problem solutions or decisions, and relevant decision criteria. There is a variety of methods to compare the alternatives. In Phase 3 different matrices are elaborated: the impact matrix evaluates alternatives based on the criteria, and the social impact matrix evaluates the alternatives based on stakeholders' opinions, preferences, and views. The social impact matrix allows the visualization of a so-called dendrogram of coalition formation, which shows possible alliances among stakeholders and pictures the coalitions that might be established according to similarities in opinions (more details in Munda 2008; De Marchi et al. 2000; Munda et al. 1995). The social impact matrix and the dendrogram of coalitions are the two key tools to integrate stakeholders' perspectives in the decision-making

process, to consider their views and to anticipate conflicts. Phase 4 concludes the process by pairwise comparing criteria and weighting alternatives

SMCE, is not by definition a co-production method, but can be designed as such given sufficient attention is paid to stakeholder identification and involvement.

Origin

Traditional MCA methods alone often prove insufficient when confronted with the stakeholders' different definitions of the problem to be addressed or with the integration of stakeholders' perspectives on their preferred alternative. As a result, several variants of multi-criteria methods have been developed to accommodate the participation of stakeholders (e.g., Messner et al. 2006; Kiker et al. 2005; Yatsalo et al. 2007). Stakeholders may play a relevant role in the identification of alternatives, in the selection of criteria and their weighting, and/or in the evaluation of alternatives (Mustajoki et al. 2004; Hamalainen et al. 2001).

Table 22: SMCE practical aspects

Support material	○ Simple
Stakeholder management process	○ Not specified
Min. time	6 months
Min. stakeholder events	n.a.
Min. and max. # of stakeholders	10-15
Min number of facilitators	1+1 per break-out group
Facilitation skills needed	○ Intermediate
Type of outcome	○ Scenarios
Approach has been used in combination with a quantitative model	○ N.a.

Applications (including at IIASA)

For example, Paneque Salgado et al. (2009) did an SMCE to evaluate the urban water supply alternatives in Costa del Sol Occidental (Malaga, Spain). The engagement of stakeholders allowed for the exploration of a non *a priori* foreseen alternative and proved extremely helpful for problem structuring in a collective, flexible, and iterative way. This process unveiled existing water management conflicts and their motivations, and improved the quality and effectiveness of information exchange. More precisely, the social impact matrix and the dendrogram of coalitions revealed that the public authorities' problem framing in terms of water scarcity and "structural water deficit" did not coincide with the stakeholders' perspectives. The majority of stakeholders framed the problem in terms of inadequate management, criticizing the lack of forward planning in a geographic area suffering the effects of unbounded growth, as well as a lack of coordination among the authorities (e.g. those responsible for water management

and for land use planning). This matrix provided useful insights not only into diverse stakeholder views but also into which alternatives were most likely to be accepted.

Systems analysis and SMCE

Understanding the system structure, including recognizing interconnections and identifying and understanding when interconnections form feedback-loops, is not at the core of SMCE. However, the approach gives specific instructions concerning problem framing, which is often grounded on the results of institutional analysis (e.g., stakeholder interviews or questionnaire surveys). Institutional change and coalition formation - as examples of analysis of dynamic behaviors - play a central role in SMCE. However, conceptual models, concept maps and leverage points do not play a critical role.

Table 23: SMCE and systems thinking

System purpose and boundaries	○ Yes (partially)
Causal relationships and feedback	○ Yes (partially)
Dynamic behavior	○ No
Conceptual models and concept maps	○ No
Leverage points	○ No

Justice and SMCE

Social justice considerations are at the core of SMCE. First, participant selection is based on institutional analysis, including stakeholder mapping and analysis of responsibility allocation. Second—as opposed to traditional MCA, in which experts identify and assess alternatives – SMCE aims at providing a representation of stakeholders' opinions and views about different alternatives. Third, the social impact matrix and a dendrogram of coalition formation are used to analyze and discuss power dynamics among stakeholders. Thus, even if a formal justice assessment is not included in SMCE, the potential for addressing/discussing justice and fairness issues is high, as shown in several case studies that use this approach (for an overview see Munda 2008).

Table 24: SMCE and justice

Participant selection	○ yes
Distribution of results	○ yes
Justice in context	○ yes
Distributions explicit	○ potentially
Distributive principles	○ No

4.9 Participatory scenario planning (PSP)

Essential features

Scenarios as a decision-making tool help us to better understand the implications of a wide range of future possibilities considering existing development, current or proposed strategies, and global interdependencies. Scenarios should be co-produced with their users. Scenario users include, for example, planners and decision makers at different scales. In a typical scenario building process, users together with researchers create alternative versions of future governance arrangements and respective socio-economic development with respect to a jointly framed problem. They have to navigate areas where they can effectively make decisions and develop policies, and areas where they need to agree on the most important but uncertain drivers. These drivers are frequently global and impinge on the decision-making space of national and sub-national actors.

The IIASA-CRS participatory scenario planning tool consists of four essential steps (Figure 12):

Step 1 "Building an understanding of the system and current situation" requires a combination of desktop research and participatory consultations. Desktop work will include a review of available information on the case study area and preliminary stakeholder mapping. Consultations can be bi-lateral (e.g., interviews, phone calls) in the first place to refine the mapping of stakeholders, followed by a multi-stakeholder interaction (e.g., workshop) to understand stakeholders' perspectives about the system, its boundaries, data available and priority needs.

Step 2 "Developing visions and pathways under business as usual", requires a participatory approach to develop the vision and identify pathways by means of back-casting (understood as) that will contribute to materializing the proposed vision.

Step 3 "Developing visions and pathways to desired futures", involves the same process as in step 2, but here the desired futures start from clear and ambitious, yet realistic, visions of what can be achieved. Since different stakeholders have different values and priorities, it is legitimate to explore a diverse set of desirable futures instead of a single one based on their value preferences.

Step 4 "Improving the robustness of pathways" requires considering undesired global scenarios. Alternative global scenarios are introduced with a set of externally imposed challenges along the analyzed regional pathways—e.g. the IPCC Shared Socioeconomic Pathways (O'Neill et al., 2013, 2017) —to provide a global context and delimit the sphere of uncertainty.

The four-step approach requires a set of in-person workshops (preferred) but there is a possibility of developing the exercise online (using boards such as Miro and Zoom). As a preparatory step, scoping interviews help to understand the main challenges in the region and to inform the workshop design. The first workshop corresponds with Step 1 of the process, a second Workshop 2 can cover Steps 2-4. If combined with modeling tools, a third workshop will support the presentation and validation of the quantitative scenarios elaborated based on the narratives of Workshop 2.

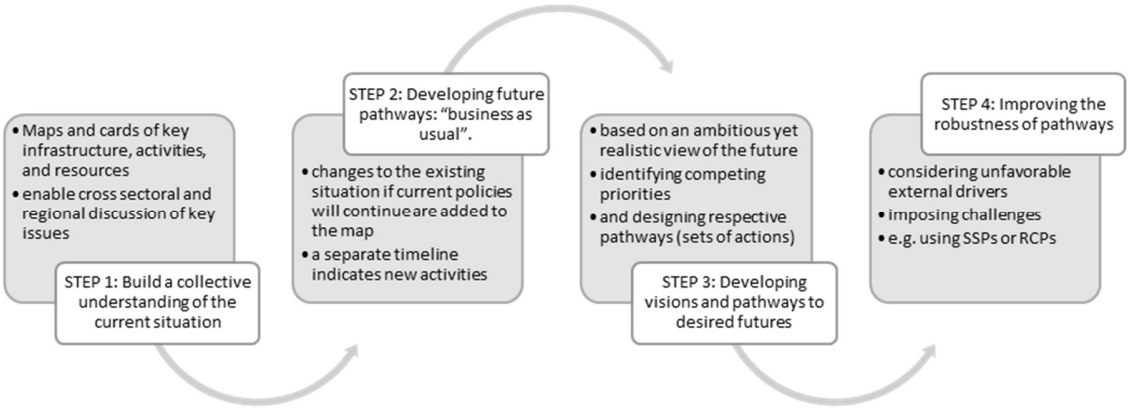

Figure 12: The four steps of the IIASA-CSR scenario tool.

Origin

Scenarios have been used widely in the private sector as a tool for strategic decision making (Van der Heijden 1996), and their use in the public sector, although less extensive, is also increasing, especially in planning contexts. Their value largely lies in the fact that they are useful as a means for communication e.g., to incite a discourse or to make scenario users sensitive to plausible future developments (Gaßner and Steinmüller, 2018).

Their impact in the public sector has so far been limited to what is considered as the first stage of the policy cycle in which policy issues are identified and framed (Volkery and Ribeiro 2009). The beneficial uses of scenarios in this context are summarized in Table 25.

Table 25: Forms in which scenarios can support policy development. Source: Volkery and Ribeiro (2009).

Policy stage	*Form of scenario-based decision support*
Policy issue identification and framing	Stimulating wider debate about possible futures Getting stakeholders engagement and buy-in Clarifying issues importance with respect to stakeholders' needs and expectations Agreeing objectives
Policy measure development	Generating options for future actions Appraising robustness of options for future actions
Policy measure implementation	Using scenario framework and indicators for monitoring of results
Policy evaluation	Using shared understanding about stakeholders' needs, expectations and objectives as well as monitoring results to assess policy effectiveness and efficiency.

Application (including at IIASA)

Scenario building is at the heart of IIASA's work. There is a long list of projects at IIASA where stakeholders have been involved in some stage of the scenario development process, but only a few such experiences reflect a true co-production process. Here we would like to highlight the ISWEL project (Integrated Solutions for Water, Energy, and Land, 2016-2020), which aimed at developing tools and capacities for the water-food-energy nexus at global and regional scales. As part of the regional assessment, the project focused on two transboundary basins facing multiple development and environmental challenges: the Zambezi Basin in southern Africa and the Indus Basin in south Asia.

The approach in the two basins was bottom-up driven, i.e. the interdisciplinary research team worked with local stakeholders closely from the beginning to identify the nexus challenges to be further explored and the type of knowledge and outputs that were considered useful and should be generated. Given the scientific capacities within the IIASA team comprising the Water, Energy and Ecosystem Services and Management programs, this approach required the integration of different type of tools, including several IIASA models (CWATM, ECHO, GLOBIOM and MESSAGE) and qualitative approaches (participatory systems mapping and visioning). The methodological approach is described by Wada and colleagues (2019). The most important innovation is the combination of participatory scenario design and integrated assessment models to translate the stakeholder narratives into quantitative scenarios (Figure 13).

Table 26: PSP - practical characteristics.

Support material	○ Elaborate
Stakeholder management process	○ Not specified (implied)
Min. time	6 months (qual. process only)
Min. stakeholder events	2
Min. and max. # of stakeholders	15-30
Min number of facilitators	1+1 per break-out group
Facilitation skills needed	○ Intermediate – advanced
Type of outcome	○ Narratives, social learning, systems thinking
Approach has been used in combination with a quantitative model	○ Yes

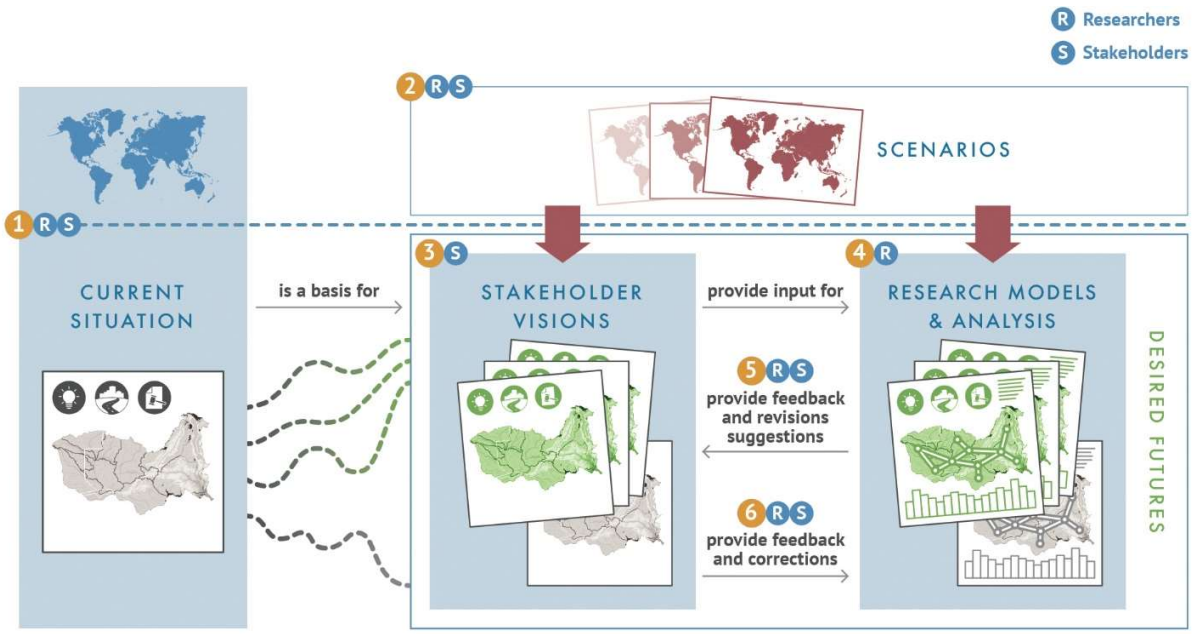

Figure 13: Co-production process implemented in the ISWEL project and based on scenario co-design (Source: Wada et al. 2019).

Systems analysis and PSP

Building a collective understanding of the system under investigation is at the heart of PSP. By using system mapping techniques involving the use of geographical and/or physical maps and cards, a wide variety of system elements (e.g., resources, pressures, socio-economic activities, risks, institutions, etc.), and a well-defined facilitation process; stakeholders identify collectively the main physical, socio-economic and institutional features, system boundaries, as well as key challenges from the different knowledge perspectives. System elements that do not have specific spatial representation, e.g. governance aspects dealing with institutions, regulations, power dynamics, etc. can be made explicit outside the maps with additional dedicated card sets. The system mapping exercise helps to display the main elements of the system in a map, but it does not address explicitly the relationships between these system elements. Indeed, in recent projects research experimented with adding conceptual mapping exercises using the mapped elements.

For understanding system purpose and boundaries, PSP functions as a diagnostic assessment tool. PSP compares the current situation vis a vis the desired futures of a variety of stakeholders, this way it can be used for action planning and eliciting pathways to overcome challenges or reach proposed targets. In this sense, PSP does explore dynamic behavior implicitly. More explicitly, this is possible when linking the qualitative process with quantitative models. This process allows participants to discuss the implications of certain actions on the system, and potentially to identify important leverage points.

Table 27: PSP and systems analysis elements.

System purpose and boundaries	○ Yes (implicitly)
Causal relationships and feedback	○ Potentially
Dynamic behavior	○ Yes (implicitly or via quant model)
Conceptual models and concept maps	○ Potentially
Leverage points	○ Potentially

Justice and PSP

The PSP does not explicitly deal with justice aspects, although there are some elements of the process that explicitly (procedural) and implicitly (distributive) address justice. One is during the initial stages when developing the mapping of stakeholders to be involved in the PSP. The approach in PSP starts with the development of a long list of actors who are connected or familiar with the problem(s) at stake (local/regional/national decision makers, practitioners, NGOs, scientists, industry representatives, non-government actors, among others). Given that often challenges are cross/sectoral, it is important to carry out a detailed mapping per sector to avoid leaving important stakeholders out. The list can be completed through snowball techniques i.e., asking identified stakeholders who else needs to be considered. Once the list is completed, an expert-based analysis can be carried out to discern stakeholders level of interest they have in challenge(s) to be addressed and their influence over its process and outcomes. If the scientific team is not familiarized with the different stakeholders, information on their level of influence and interest can also be collected through interviews and desktop review. Through this clustering it is possible to discern stakeholders who have little influence but high interest in the problems to be addressed, and which normally overlap with less represented groups.

Furthermore, the PSP process also explicitly recognizes that stakeholders have different worldviews and priorities, and the process is designed to allow for the exploration of alternative desirable outcomes (visions) based on stakeholder values. The resulting visions and associated pathways will prioritize certain actions and values, and this is used to debate emerging synergies and trade-offs as well as potential winners and losers. The PSP tool is very flexible, and therefore, dimensions of both distributive and procedural justice can be further integrated. In terms of distributive justice, the assessment of costs and benefits of different development pathways reveal the benefits and trade-offs for upstream and downstream countries, although without distinguishing groups of actors when using integrated assessment models. Agent-based models will enable such a distinction.

Table 28: PSP and justice.

Participant selection	○ no
Distribution of results	○ no
Justice in context	○ yes
Distributions explicit	○ yes
Distributive principles	○ no

5 Discussion and outlook

We explore two fundamentally different yet mutually beneficial aspects that are becoming increasingly important in knowledge co-production: justice, as a value assessment, and the capacity to implement and enable systems thinking. Beyond these two issues, our review highlights that participatory processes are not inherently knowledge co-production methods. Rather, it is the way they are implemented and facilitated that determines the extent to which they support the benefits of knowledge co-production. This also applies to their ability to address justice and enhance systems thinking.

Participatory methods that follow key knowledge co-production criteria, such as pluralism and inclusiveness, foster systems thinking by providing diverse perspectives on an issue, thereby enabling more holistic approaches. Among the specific criteria defined here, we find that few approaches—apart from those directly emerging from systems dynamics—consider more than system purposes and boundaries. However, many provide entry points for making causal relationships and feedback explicit. Methods linked to quantitative models are also capable of highlighting dynamic interactions.

Opportunities to explicitly foster systems thinking lie in visualizing insights from the process through simple yet clear systems diagramming and concept mapping—i.e., drawing relationships using nodes, edges, and clear labels. This approach directly links to and can be particularly useful in identifying and discussing leverage points.

Justice relates to knowledge co-production in two key ways. First, through aspirations such as inclusiveness, pluralism, and equal partnerships, it incorporates procedural justice norms and can thus be considered a means of achieving just research processes. Second, it creates space for dialogue on justice and justice assessment. Methods that perform relatively well in the first aspect include Social Multi-Criteria Analysis and Plural Rationality approaches. Other approaches do not actively enhance the justice of the process itself.

All the approaches introduced here provide an excellent setting for dialogue on justice and justice assessment in various contexts. However, a strong understanding of different forms of justice and justice principles is essential. The proposed assessment framework is not yet equipped to provide the necessary depth of information, and we will consider other frameworks in the future. Additionally, while several methods can make the distributive implications of an issue explicit, none fully incorporate principles of distributive justice.

This report serves as a more detailed follow-up to the fairSTREAM co-production toolkit, specifically examining the capacity of these methods to foster systems thinking and justice considerations. It also serves as a reference for research in fairSTREAM WP3. This work has inspired the following next steps:

- Develop TDR and knowledge co-production principles, along with guidance for applying them in participatory processes.
- Engage with IIASA colleagues and other peers working on TDR and knowledge co-production.
- Design a justice framework to assess justice issues in a TDR setting.

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7 Annex – Score cards explained

Table 29: Practical characteristics of the method – ref score card.

Support material Material and equipment needed for implementation	○ None ○ Simple ○ Elaborate
Stakeholder management process Is stakeholder identification and communication explicitly part of the method?	○ Not specified ○ Elementary ○ Detailed
Min. time for planning, design, implementation and debrief	[enter number]
Min. stakeholder events group events	[enter number]
Min. and max. # of stakeholders	[enter lower and upper bounds]
Min number of facilitators for group events	[enter number]
Facilitation skills needed	○ Basic ○ Intermediate ○ Advanced
Type of outcome does the method produce a specific product or predetermine a specific outcome?	○ Predetermined ○ Flexibel ○ n.a.
Approach has been used in combination with a quantitative model	○ Yes ○ No ○ n.a.

Table 30: Systems analysis elements that are explicitly addressed in the approach or can potentially be included without substantially changing the approach.

System purpose and boundaries	○ Yes ○ Potentially ○ No ○ n.a.
Causal relationships and feedback	○ Yes ○ Potentially

	○ No ○ n.a.
Dynamic behavior	○ Yes ○ Potentially ○ No ○ n.a.
Conceptual models and concept maps	○ Yes ○ Potentially ○ No ○ n.a.
Leverage points	○ Yes ○ Potentially ○ No ○ n.a.

Table 31: Justice elements that are explicitly addressed in the approach, or can potentially be included without substantially changing the approach.

Participant selection does the method specify how participants are selected	○ yes ○ potentially ○ no ○ n.a.
Distribution of results	○ yes ○ potentially ○ no ○ n.a.
Justice in context procedural and/or distributional justice issues can easily be the thematic focus of the approach	○ yes ○ potentially ○ no ○ n.a.
Distributions explicit Distributions of goods/outcomes are made explicit through the application of this approach	○ yes ○ potentially ○ no ○ n.a.
Distributive principles this approach implies or suggests certain distributive patterns	○ yes ○ potentially ○ no ○ n.a.


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