C

Change Scenarios for Sustainable Development

Julia Swart
Utrecht School of Economics, Utrecht University, Utrecht, The Netherlands

Synonyms

Climate change scenarios; Pathways to sustainable development; Strategic environmental assessment; Sustainability forecast; Trend analysis for sustainable development

Definitions

Change scenarios for sustainable development consider alternative viable assumptions about future socioeconomic indicators and policies which affect local, regional, or global sustainable development. Scenarios are according to the United Nations (2014, p. 62) "plausible and internally consistent picture of the future. They are useful tools – often making use of quantitative models – to systematically explore the feasibility of visions and proposed future pathways towards their achievement. They provide information on the means of implementation that are needed and can be useful in monitoring progress."

Change scenarios differ from trend analysis for sustainable development by incorporating uncertainty, in particular in terms of environmental issues. UNEP (2004) argues that "scenarios offer a means for examining the forces that shape our world, the uncertainties that lie before us and the implications for tomorrow of our actions today. A scenario is also a story, told in words and numbers, concerning the manner in which future events could unfold; analysis of a range of scenarios offers lessons on how to direct the flow of events towards sustainable pathways and away from unsustainable ones." Thus, whereas scenarios do not set in stone how the future will look like in terms of sustainability and economic development, it does allow us to make a more conscious choice of how society wants to live today, given how these choices could affect the lives of future generations.

Introduction

Imagine a world where we could predict with certainty the environmental consequences of human actions such as consumption, production, and technological discoveries. Could we then increase our well-being today? If individuals only care about the present, then the answer would be closer to a no (unless environmental impacts were felt instantaneously). However, in reality we all care to some extent about the future (in particular the near future). Given that we care about the future, knowing how our actions today affect the environment provide us with valuable

W. Leal Filho et al. (eds.), *Partnerships for the Goals*, Encyclopedia of the UN Sustainable Development Goals,
https://doi.org/10.1007/978-3-319-71067-9_22-1

information to improve our own well-being. Alternatively, lack of knowledge about the environmental impact of our actions decreases our well-being without us even noticing it. Predicting the future, however, is not possible. If it was, numerous environmental and humanitarian catastrophes could have been prevented. An historical example can help illustrate this.

From the production side, we are nowadays aware that ingestion of fishes from water contaminated with methyl mercury leads to the Minamata disease. The name of this disease makes reference to the hefty poisoning of residents from the surroundings of the Minamata Bay, in Japan, in the beginning of the 1950s. Ekino et al. (2007) report more than 2000 deaths from this disease since then and about 200,000 cases of poisoning. Negligence from the manufacture firm disposing contaminated wastewater on the Minamata Bay has led to large compensation costs to the victims. All parties involved lost from this ecological disaster. It was certainly better from an economic, environmental, and well-being point of view to have prevented the mercury to enter the river and from there the sea. This environmental impact was not known to the policy makers in the early twentieth century. Given that it is known today, countries and regions can analyze different scenarios of mercury contamination on future well-being (for an instance, based on different regulation levels and production levels) to decide on the most fair, environmental-friendly, and efficient policy.

This example shows that society can benefit from understanding the possible impacts of socio-economic factors (or most straightforwardly, human action) on the environment. The closer we can forecast these impacts, the more equipped we are to make well-informed decisions about what we eat, how we commute, what we dress, and more generally how rules and regulations can be implemented to increase society's well-being today while considering the well-being of future generations. While making forecast or trying to predict the future might be intangible, thinking about different possible scenarios allows us to envision how the future might disclose.

The idea behind forming scenarios is to create a roadmap of alternatives to which decision-making can be reliably made. Different scenarios can be set out by changing factors such as regulation and production level. Van Notten (2006) emphasizes that there are different definitions of scenarios, but they all have in common that scenarios are not predictions of the future; and these alternative definitions all characterize scenarios as "hypothetical, causally coherent, internally consistent, and/or descriptive." Furthermore, through scenario analysis, a plan of actions can be set. Methodologically speaking, Van Notten (2006) distinguishes scenario analysis into two: analytical and intuitive design. Analytical approaches encompass model-based techniques which involve quantifying uncertainties but can also be "desk research," that is, document analysis and archival research. Intuitive design, on the other hand, is based on qualitative knowledge to develop the scenario.

Scenarios can be related to modeling activities, but are not to be confused with Environmental Impact Assessment. Environmental Impact Assessment quantifies the environmental impact of a specific economic activity for given parameters and circumstances. Glasson et al. (2005) provide a few often-cited definitions of Environmental Impact Assessment, one of them being the broad definition of Munn (1977) who defines it as "an activity designed to identify, predict, interpret and communicate information about the impact on man's health and well-being, of proposed major actions such as the construction of large engineering works, land reform, and legislative policy and program proposals" (p. 135). This definition approximates the one from change scenarios, causing the confusion. A more succinct definition adopted by the United Nations defines Environmental Impact Assessment as a "systematic process to identify, predict and evaluate the environmental effects of proposed actions and projects" (UNEP 2002, p. 103). It can therefore be seen as a policy tool to evaluate specific projects, such as adoption of new technologies and infrastructure.

Change Scenarios: A Relatively New Approach

Environmental concerns started to increasingly take part of policy decisions in the 1950s. In the academic sphere, environmental studies developed to be a fast-growing discipline in the 1970s. By then sustainability became as well a sub-discipline from different fields, such as economics and geography. Nowadays, a diversity of disciplines has sustainability as a core focus area (e.g., philosophy, political sciences, and cultural studies). Robertson (2017) argues that in the 1960s–1970s public awareness of environmental problems arising from, for example, pesticide use and population growth promoted the formation and development of environmental framework and regulation. In the USA, for example, the National Environmental Policy Act was signed into law in 1970.

The year 1972 was, in particular, an important year for the field of sustainability. It was the year of the publication of *Limits to Growth* by the Club of Rome (Meadows et al. 1972). The *Limits to Growth* was influential and set a turning point in the sustainability field because it provoked different stakeholders to rethink the impact of economic activities onto the future generations. The authors have analyzed trends of five indicators – population, capital, food, nonrenewable resources, and pollution – while taking the interrelationships among them, to set up a world model through which they could investigate the world system's "behavioral tendencies" (p. 93). The authors analyzed a few scenarios (which they name alternatives or runs) which are based on a specific set of assumptions (e.g., constant population growth) to analyze the impact on the world system for a period of 100 years. The Club of Rome was the first work to present a comprehensive change scenario analysis undertaken at a global scale.

At around the same period, Environmental Impact Assessment (EIA) was established, first in the USA (1969) and soon after in Europe and other developed countries (e.g., Canada and Australia). UNEP (2002) identifies four overlapping phases in its evolution, which in a nutshell consists of (i) development of EIA in developed countries (1970s); (ii) increasing scope and sophistication of EIA and diffusion to developing countries (mid-1970s to early 1980s); (iii) process strengthening and integration (early 1980s to early 1990s); and (iv) strategic and sustainability orientation (early 1990s onward) (p. 109). Furthermore, more recently countries, such as in the European Union, have introduced Strategic Environmental Assessment (SEA), which "informs a higher, earlier, more strategic tier of decision-making" (Glassan et al. 2005, p. 7). Strategic Environmental Assessment is more comprehensive than Environmental Impact Assessment in the sense that it not only analyzes projects, but it also does so for policies.

The United Nations Economic Commission for Europe (UNECE) has a protocol on SEA, which defines it in Article 2.6 as ". . . the evaluation of the likely environmental, including health, effects, which comprises the determination of the scope of an environmental report and its preparation, the carrying-out of public participation and consultations, and the taking into account of the environmental report and the results of the public participation and consultations in a plan or programme" (UNECE 2016, p. 3).

To conclude this introduction section, we turn back to the water contaminated with methyl mercury case, to emphasize the difference and interconnectedness between change scenarios for sustainable development and Environmental Impact Assessment. Through Environmental Impact Assessment, one can define what the environmental impact of a factory dumping methyl mercury would be to the local biodiversity, human health, and other relevant indicators. Such data can thereafter be used in a model looking at trends in different indicators (e.g., population size, industrialization rate, etc.) and their impact on local, regional, or world systems. Furthermore, although most academic articles emphasize quantitative change scenarios, scenarios can involve both qualitative and quantitative analysis and can be grouped into three distinct types: predictive, explorative, and normative (Börjeson et al. 2006).

In the following two sections, we discuss first, the connection between change scenarios and the

Sustainable Development Goals, and second, the interdisciplinary nature of scenario analysis and a well-known application of scenario analysis coordinated by the IPCC, whose contribution allows policy makers to think through policies which foster sustainable development. The final section provides concluding remarks.

Change Scenarios and the Sustainable Development Goals

In September 2015, 193 world leaders met in New York under the umbrella of the United Nations. These leaders agreed to follow 17 Sustainable Development Goals and meet 169 targets by 2030. These goals envisage to foremost end extreme poverty, fight inequality and injustice, and fix climate change, thus embracing social, economic, and environmental aspects. The Sustainable Development Goals (henceforth: SDG) expand on the Millennium Development Goals (a global effort starting in the year 2000 to combat poverty) by incorporating new areas such as climate change and sustainable consumption. To meet these goals, countries and regions should consider that these goals are integrated. Thus, for example, fighting poverty goes hand in hand with providing solutions to climate change; fighting inequality within countries (SDG 10) requires promotion of decent work for all (SDG 8), good health and well-being (SDG 3), and quality education (SDG 4), to name a few.

Meeting these integrated goals demands an integrated system of solutions (UNEP 2019). The United Nations Development Programme (UNDP) has for that purpose setup four workstreams to provide support to countries to outline policies and programs which are conducive to meet the SDGs while recognizing the complexity and integration of these goals. One of the workstreams is “data and analytics,” which uses integrated modeling frameworks as a tool to assist countries in identifying future scenarios. These scenarios, in turn, are recognized as fundamental to the establishment of policies which guarantee that the SDGs are met. An example of a toolkit to explore forecasting based on alternative scenarios is the International Futures (IFs) which is used by different planning and development organizations, including the UNDP (Hughes et al. 2004 explain the structure of the IFs modeling system). Scenario analysis has been overall widely used to analyze long-term impact of alternative states and situations, thus facilitating decision-making.

While it is broadly accepted that scenario analysis is an integral part to assist in the implementation of the SDGs, there is a range of models used in the academic literature. Some models might be more suitable to analyze specific circumstances, but there is no consensus in the literature on which model to adopt to analyze policies to achieve the SDGs. Dynamic computable general equilibrium models (dynamic CGE models) are often adopted, for example, when there is a solid theoretical framework which incorporates feedbacks across different sectors and spillovers from policy changes. CGE models are one of the most used models to analyze climate change impacts. Nonetheless, an alternative type of model for climate change, integrated assessment models (IAMS), is also often adopted, in particular when larger focus on the interactions between the economic and the biophysical system is described (see e.g. Wellman and Hunt 2016; and OECD 2015).

Allen et al. (2016) conduct a comparative assessment of 80 models to address their relevance for national SDG planning. As part of their research, they surveyed 70 modeling experts from diverse backgrounds (academia, research, national development planning) regarding a review of criteria used in comparative assessments of models and regarding attributes of the SDGS which are relevant for modeling. From the selection of the 80 models, the authors made an inventory of the modeling options used in national SDGs planning and identified eight model categories: (i) hybrid models; (ii) CGE models; (iii) top-down system dynamics models; (iv) bottom-up optimization/partial equilibrium models; (v) bottom-up simulation models; (vi) macro-econometric models; (vii) input-output models; and (viii) bottom-up multi-agent models (the next subsection provides a brief description of each of these model categories). The first two – hybrid models and CGE models – account for close to 60% of all models analyzed. Furthermore, their finding shows that the selection of the most effective modeling approach and type depends on various factors (e.g., data availability, cost limitations, sector of analysis, and interactions between sectors), which need to be considered in order to select the model. Additionally, with respect to the SDGs, the authors recommend combining different models which address the relationship of particular sectoral issues.

Table 1 summarizes some of the findings from Allen et al. (2016) by indicating the number of models which are relevant for the 17 Sustainable Development Goals, disaggregated by the model category. Figure 1 shows the finding when we add up through the model categories. Table 1 and Fig. 1 show that the three SDGs which have been represented the most in the models ("highly relevant" and "somewhat relevant") are SDG8, Decent work and economic growth, with 64 out of 80 models taking this SDG into account; SDG13. Climate Change, with 61 out of the 80 models; and SDG7, Affordable and clean energy, with 59 out of the 80 models. On the other extreme, the less represented SDG in scenario analysis models were SDG16, Peace, justice, and institutions, represented by only 3 models; SDG 5, Gender equality, with 4 models; and SDG 14, Life below water, with 6 models.

Eight Model Categories for Scenario Analysis

Hybrid Models

Hybrid models are used for analyzing complex environmental systems (e.g., where social and ecological interactions are present). Vincenot et al. (2016) define it as "the combination of simulatory approaches aimed at the accurate mechanistic modeling of complex dynamic systems. It basically consists in the coupling – to a varying degree ranging from simple comparison to bridging to total fusion – of models based on different existing modeling techniques." Hybrid models emerge when separate models describe parts of a larger system under investigation. Furthermore, they are often used when bottom-up and top-down views of a system need to be aligned. Examples of hybrid models are International Futures, DICE and RICE, and PAGE.

CGE Models

Computable general equilibrium models are widely used by economists as a tool for policy analysis. All CGE models start from the basic representation of the circular flow model of commodities in a closed economy, represented by consumers, firms, and a government. As defined by Sue Wing (2004), CGE models "are simulations that combine the abstract general equilibrium structure formalized by Arrow and Debreu with realistic economic data to solve numerically for the levels of supply, demand and price that support equilibrium across a specified set of markets." This type of models is widely used to analyze the impact of policies on income distribution and on welfare while taking the interactions in various markets. As such, CGE models are used across diverse areas, including environmental regulation; and they serve as a tool for empirical analysis. An example of a CGE model is the GEM-E3 (UN 2020) which is a recursive dynamic CGE model that takes into account links between the economy, the energy system, and the environment.

Top-Down System Dynamics Models

Top-down approaches to complex problems focus on the broad view of the problem, as opposing to the bottom-up approach which focuses more on the details (e.g., heterogeneity) underlying the systems. Top-down system dynamics models provide the tools to understand the dynamic behavior of systems while considering that various aggregated system compartments are interrelated and connected. Pruyt (2013) defines system dynamics as "a method to describe, model, simulate and analyze dynamically complex issues and/or systems in terms of the processes, information, organizational boundaries and strategies." Furthermore, it applies "the principles and techniques of control systems to organizational and social-economic-environmental-... problems." The *Limits to Growth* report by the Club of Rome (Meadows et al. 1972), the first work to

Change Scenarios for Sustainable Development, Table 1 Scenario analysis models analyzed by Allen et al. (2016) and the relevance to the 17 Sustainable Development Goals

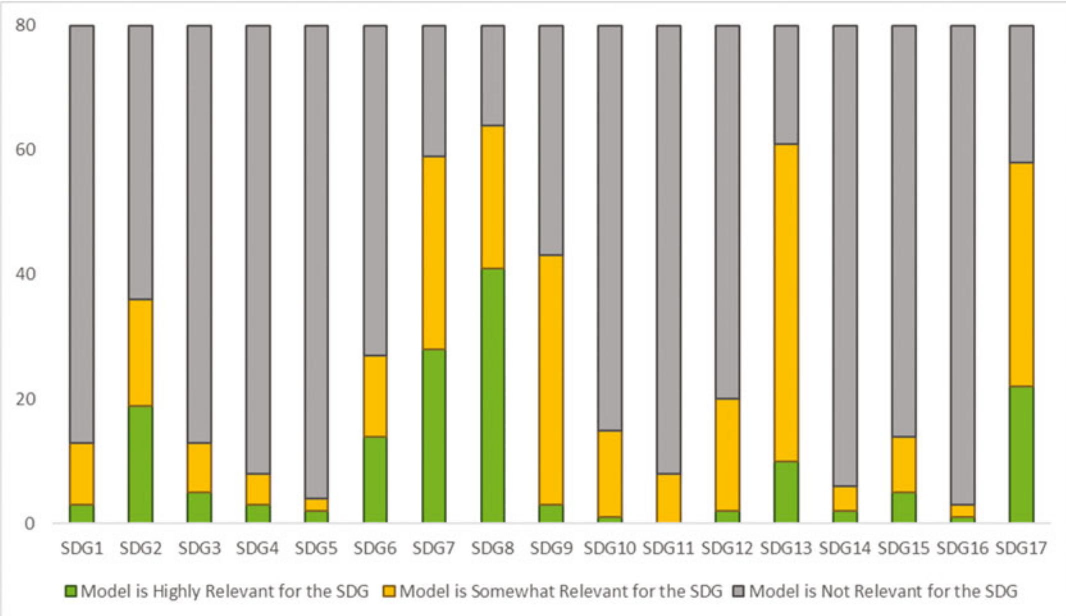
First row	Number of models that are **highly relevant** for the SDG
Second row	Number of models that are **somewhat relevant** for the SDG
Third row	Number of models that are **not relevant** for the SDG

Analytical Approach & Model Category	Number of models	SDG 1	SDG 2	SDG 3	SDG 4	SDG 5	SDG 6	SDG 7	SDG 8	SDG 9	SDG 10	SDG 11	SDG 12	SDG 13	SDG 14	SDG 15	SDG 16	SDG 17
Top-down input-output models	5	0	0	0	0	0	0	0	2	0	0	0	1	0	0	0	0	2
		0	4	1	0	0	4	4	3	4	2	0	3	3	1	0	1	2
		5	1	4	5	5	1	1	0	1	3	5	1	2	4	5	4	1
Top-down econometric models	6	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	2
		0	1	0	0	0	0	4	0	4	0	1	1	3	0	0	0	4
		6	5	6	6	6	6	2	0	2	6	5	5	3	6	6	6	0
Top-down CGE models	15	0	0	0	0	0	0	0	14	0	0	0	0	0	0	0	0	13
		7	3	1	2	0	1	9	1	13	5	0	0	7	0	0	0	2
		8	12	14	13	15	14	6	0	2	10	15	15	8	15	15	15	0
Top-down system dynamics and simulation models	8	0	2	1	0	0	1	1	1	1	0	0	1	0	0	0	0	0
		1	4	1	1	0	4	4	6	5	2	4	3	7	1	3	0	3
		7	2	6	7	8	3	3	1	2	6	4	4	1	7	5	8	5
Bottom-up optimisation/ Partial equilibrium models	8	0	1	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	1	2	1	2	0	0	0	7	0	0	0	6
		8	7	8	8	8	7	0	7	6	8	8	8	1	8	8	8	2
Bottom-up simulation models	6	0	1	0	0	0	1	4	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	1	3	1	0	0	1	4	0	0	0	3
		6	5	6	6	6	5	1	3	5	6	6	5	2	6	6	6	3
Bottom-up multi-agent models	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	1	0	1	0	0	0	0	1	0	1	0	0
		1	0	1	1	1	0	1	0	1	1	1	1	0	1	0	1	1
Hybrid models	31	3	14	4	3	2	12	17	18	2	1	0	0	10	2	5	1	5
		2	5	5	2	2	2	7	8	11	5	3	10	19	2	5	1	16
		26	12	22	26	27	17	7	5	18	25	28	21	2	27	21	29	10

present a comprehensive change scenario analysis undertaken at a global scale, is based on system dynamic models.

Bottom-Up Optimization/Partial Equilibrium Models

Bottom-up optimization or partial equilibrium models analyze specific markets within the economy, as opposed to general equilibrium models which deal with the entire economy. Partial equilibrium models show how a change within a specific market (e.g., on preferences or costs) affects production and consumption in that market. This type of models is behind influential models used for environmental policy decisions, including FUND, GCAM, IMAGE/TIMER, and PRIMES. The PAGE (Policy Analysis of Greenhouse Effect) Model has elements of a partial equilibrium model. This model received a lot of attention in the policy debate, as it was applied in



Change Scenarios for Sustainable Development, Fig. 1 Relevance of 80 scenario-based models for the 17 Sustainable Development Goals. (Based on Table G from the Supplementary Material in Allen et al. (2016))

the *Stern Review* (Stern 2007). The *Stern Review* had strong policy implications and recommended immediate action to contain greenhouse gases emissions. As another example, the European Commission uses the PRIMES energy model (EC 2020), created in 1993 (E3MLab 2014) to analyze energy markets, by simulating energy consumption and the energy supply system. This model allows forecasting, change scenarios, and analysis of policy impact.

Bottom-Up Simulation Models

Bottom-up simulation models are similar to bottom-up optimization models in the sense that they also center on a specific market, for example, the energy market or the irrigation sector. An additional characteristic from these types of models is that they adopt a technological representation which is based on a rational-decision process. That is, the model assumes that decision-makers have perfect knowledge of which technologies are more efficient and face little barriers to adopt them (Fleiter et al. 2011). Fleiter et al. (2011) compare bottom-up optimization models with bottom-up simulation models used in energy markets and state that "while optimization models optimize the choice of technology alternatives with regard to the total system costs to find the least-cost path, simulation models lack this system optimization perspective. They are very heterogeneous and some of them optimize from a firm perspective, while other do not optimize and instead consider other non-financial factors for the technology adoption decision." Simulation models are used often for scenario analysis of the energy market (see, e.g., Worrell and Price 2001 who analyze three policy scenarios to improve energy efficiency in the US industry).

Macro-econometric Models

Macro-econometric models are forecasting models based on mainly economic data. They differ from other models by the use of long-run time-series data and by their solid empirical base. Whereas CGE models rely on the Arrow-Debreu framework, the macro-econometric models adopt the neo-Keynesian framework, in which economies follow a demand-driven structure and underutilization of productive capacity is allowed in the model (Di Comite and Kancs 2015). These models use a system of dynamic equations to represent the economy and estimate the parameters of the model using long-run time-series data. In this sense, forecasts are based on past correlations. Macro-econometric models are used by diverse organizations and national institutes, including the IMF and the World Bank. The EU, for example, has supported the development of the NEMESIS (New Econometric Model of Evaluation by Sectoral Interdependency and Supply) model, which is a system of economic models for the EU countries, Norway, USA, and Japan. The model allows forecasts for different scenarios for about 30 years to facilitate policy decisions in different economic aspects, including energy regulation and fiscal reforms (Zagame et al. n.d.).

Input-Output Models

Input-output models are an analytical framework used to analyze the interdependencies of industries within an economy. It was originally developed by Leontief (1941) and consists of a mathematical structure of a set of n linear equations and n unknowns. Assuming a single economy with n sectors, an input-output representation of this economy would then have the "selling sector" on the rows of the matrix (the input-output table) and the "buying sector" on the columns of the matrix, in which the entries would identify the interindustry flows of goods in monetary terms (Miller and Blair 2009). By applying an input-output analysis, one can estimate the impact of shocks in the economy. It is used, for example, to analyze different long-term scenarios based on technological advances, environmental effects, and supply and demand developments. The Netherlands Environmental Assessment Agency, for example, uses the DIMITRI model, which is an input-output model, to study the impact of technology-related shocks (see, e.g., Faber et al. 2007 who uses the model to describe the relations between production, consumption, and emissions at the sectoral level while basing on IPCC's scenario framework). The input-output models have also been used in support of the Sustainable Development Goals. Costanza et al. (2016), for example, while investigating alternative methods to relate the SDGs to measures of well-being, propose embedding the input-output model into a dynamic, nonlinear, systems model of the economy, the society, and the natural environment. Gustavson et al. (1999) use an input-output model which accounts environmental impacts to analyze sustainable development indicators for the Fraser River Basin in British Columbia.

Bottom-Up Multi-Agent Models

Multi-agent models simulate the interactions of multiple agents through the use of computational models. Agents can be any decision-maker, from autonomous consumers and producers to groups and organizations. A bottom-up approach to a multi-agent model starts with defining the individual components, the rules, and the institutions, and as a result of the interactions between the components, the global effect can be derived. Farmer and Foley (2009) argue for the use of multi-agent models in economics as it has the advantage of not assuming that the economy will move to a certain pre-defined equilibrium. Alternatively, in this type of models, the authors explain, "at any given time, each agent acts according to its current situation, the state of the world around it and the rules governing its behaviour. An individual consumer, for example, might decide whether to save or spend based on the rate of inflation, his or her current optimism about the future, and behavioural rules deduced from psychology experiments. The computer keeps track of the many agent interactions, to see what happens over time. Agent-based simulations can handle a far wider range of nonlinear behavior than conventional equilibrium models. Policy-makers can thus simulate an artificial economy under different policy scenarios and quantitatively explore their consequences."

Change Scenarios and Fields of Research

The previous section showed that, according to Allen et al. (2016), SDG13 – Climate change – is very well represented in scenario analysis. An intuitive reason for this is the uncertainty and long-term impact associated to climate change. Given the prominent attention to climate change in the news, it is therefore understandable that change scenarios are often linked to climate forecasts. The previous section showed, nonetheless, that change scenarios encompass diverse topics. Additionally, scenario analysis can be applicable to all Sustainable Development Goals and is an important tool to better comprehend policy implications to achieve the goals. Nonetheless, the work by Allen et al. (2016) indicates that a few of the Sustainable Development Goals are still less represented by scenario analysis (see Table 1).

Scenario analysis does not, however, pertain exclusively to research. Many private organizations also conduct scenario analysis to make their business plan. Discipline wise, scenario analysis can be seen as method which crosses disciplines. In fact, all Sustainable Development Goals, such as climate change, are interdisciplinary by nature. There is a wide range of disciplines which work with scenario analysis, including geography, mathematics, engineering, and social sciences. Van Notten (2006) points out that "the process of scenario development provides a language to cross disciplinary boundaries. In organisations, it may provide a basis for 'strategic conversations,' to discuss perceptions on strategy, opportunities, and threats."

Scenario analysis promotes a connection between disciplines which is fundamental to the understanding of complex issues. Laurent et al. (2015) argue that different disciplines analyze the Great Lakes-St. Lawrence River basin, a transboundary watershed between the USA and Canada. Nonetheless, these disciplines remain isolated within their field, often using different methodologies with uncertain predictions. The authors provide five reasons for considering scenario analysis for analyzing Great Lakes basin resource management as an effective and valuable methodology: scenario analysis crosses disciplines; it takes uncertainty into account; it facilitates the creation of a common language within academia and between academia and stakeholders; scenario analysis considers diverse overlapping and interacting scales; and finally, scenario analysis opens to new insights and inquiries for future research.

Despite contributing to a more holistic understanding of social, economic, technological, and environmental dimensions of the world, scenario analysis also has its critics. A common critique is that model-based quantitative scenarios do not represent the social dimensions well enough, requiring a more systemic and integrated approach. In this sense, scenario analysis has benefited from the link created with participatory approach. In this approach, knowledge is created about how a local community or region is organized and how it functions, by counting with the participation of local actors. Walz et al. (2007), for example, use a case study on changes in agriculture in a region in Switzerland, to investigate whether and how participatory involvement has contributed to define the scenarios for a numerical simulation.

The IPCC Scenario Framework

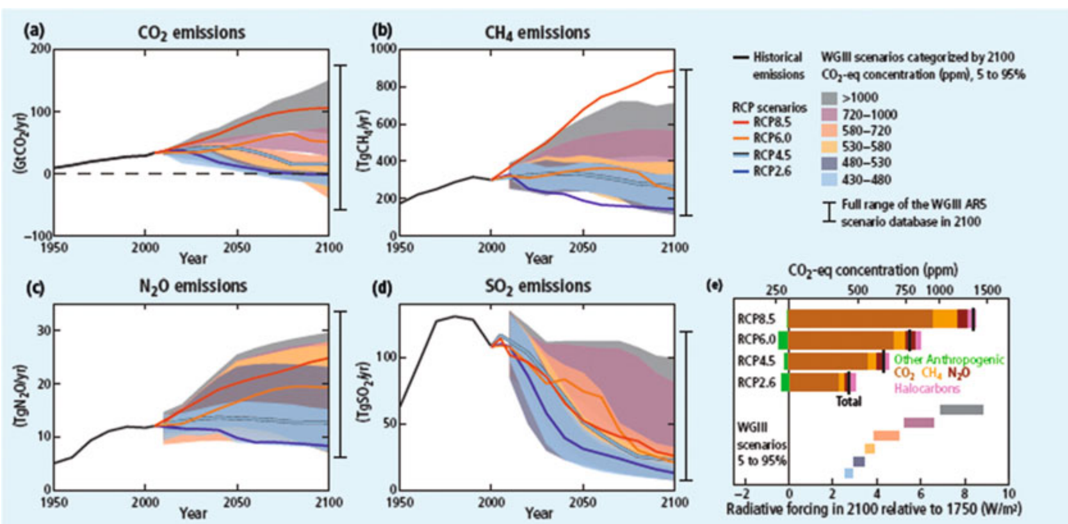
The IPCC (Intergovernmental Panel on Climate Change) is a body from the United Nations, which was created in 1988 to provide policy makers scientific assessments related to climate change. Since its creation, the IPCC has produced and made publicly available Five Assessment reports, in addition to other reports on more specific topics. Currently, the IPCC is on its sixth assessment cycle, which has already resulted in three special reports. The dates of the Assessment Reports are 1990, 1995, 2001, 2007, and 2013/2014. The sixth cycle started to produce reports in 2016 and is expected to end by 2022 with the release of the Synthesis Report. This section is based on the Fifth Assessment Report to discuss the role of change scenarios in the IPCC framework.

IPCC (2014) bases extensively on climate models to project future climate and therefore climate change. Various climate models are used, from simple idealized models to general circulation models. To produce robust projections, the climate models are tested against historical observations. To obtain the projections, the models work with a set of alternative scenarios (the Representative Concentration Pathways – RCP) of greenhouse gases emissions, air pollutant emissions, and land use patterns. The Representative Concentration Pathways comprise five scenarios: a stringent mitigation scenario (RCP2.6), two intermediate scenarios (RCP4.5 and RCP6.0), and a scenario with very high GHG emissions (RCP8.5). The baseline scenario (business as usual – BAU) lies between RCP6.0 and RCP8.5, that is, on the upper-level of GHG emissions.

Figure 2 shows emission scenarios from the Fifth Assessment Report. Panel (a) shows, for example, the emissions of carbon dioxide from 1950 until 2100 for four RCPs and historical emissions. Panel (e) shows future radiative forcing levels for the RCPs which was calculated using the MAGICC model (MAGICC – Model for the Assessment of Greenhouse Gas Induced Climate Change, http://www.magicc.org/), for the RCPs (per forcing agent) and for the WGIII scenario categories, which represents the categories considered in the Working Group III of IPCC. (The IPCC Synthesis Report considers the reports from three working groups. Working Group I focuses on the Physical Science Basis; Working Group II on Impacts, Adaptation, and Vulnerability; and Working Group III on Mitigation of Climate Change.) After setting-up these scenarios, the next step is to assess different impacts on temperature, which is done for surface temperature change but also to sea ice extent, sea level rise, and the effect on surface ocean pH. A comprehensive assessment is built around these essential, but not exclusive, elements. It is an interdisciplinary if not transdisciplinary endeavor, which supports policy makers around the world. The work from the IPCC was influential in reaching, among others, the Paris Agreement in 2015 and shows the fundamental role of scenario analysis on socioeconomic and environmental dimensions of life.

Concluding Remarks

Scenario analysis creates a roadmap of alternatives to which decision-making can be reliably made. There are a variety of approaches to conduct scenario analysis and within quantitative approaches a range of models adapted to specific regions, sectors, or variables of interest. Advances in this area of research are fast and far-reaching. Different private organizations – from middle size to large – (e.g., Boston Consulting Group, McKinsey, Shell, Unilever), institutes, and



Change Scenarios for Sustainable Development, Fig. 2 IPCC (2014) emission scenarios and the resulting radiative forcing levels for the Representative Concentration Pathways (RCPs, lines) and the associated scenarios categories used in WGIII (colored areas) national and supranational organizations and agencies use scenario analysis to guide their strategies and policy choices. It makes a fundamental impact on an individuals' life and determines course actions pertaining areas crossing a variety of fields.

Scenario analysis is also a fundamental tool given the constant changes the world faces. Society needs to create awareness of scenarios of change, that is, changes in indirect variables which affect the scenario of the interested variable in question. For example, while making a scenario analysis of biodiversity, one needs to consider the scenario of changes in variables such as carbon dioxide emissions and land use. These changes will then define how sensitive biodiversity is to different scenarios. For the Sustainable Development Goals, scenario of changes implies analyzing the links between the actions to achieve all goals simultaneously.

This work showed that there is considerable amount of academic literature using scenario analysis to analyze Sustainable Development Goals. Nonetheless, not all Sustainable Development Goals are equally represented in the literature. In particular, there is less literature on scenario analysis and SDG 16 (Peace, justice, and institutions), SDG 5 (Gender equality), and SDG 14 (Life below water). Future research should make use of the vast knowledge already available to provide better information for policy makers to reach the 17 Sustainable Development Goals and associated targets in the near future. Furthermore, it is imperative that the goals are taken together into consideration, as much as possible, in order to exploit synergies and opportunities and take eventual trade-offs of policies into account. This is off course a big challenge, as the broader the models become, the more synergies and trade-offs might become unresolved (UN 2014). Additionally, there is not one pathway to sustainable development, but scenarios can facilitate the visualization of the consequences of certain (in)actions. Finally, pathways for distinct issues, countries, regions, and sectors might also differ; thus it is important to conduct a more holistic scenario analysis which takes these specificities into account.

Cross-References

- ▶ Advancing Integrated Solutions As Key to Achieving Sustainable Development Goals in Africa
- ▶ Collaborative Methodologies for Creative Processes in the SDGs Framework
- ▶ Examining the Role of Big Data for Strengthening Multi-stakeholder Partnerships in the SDGs
- ▶ Life Cycle Assessment and Evaluation of Solutions Towards Sustainable Development Goals

References

Allen C, Metternicht G, Wiedmann T (2016) National pathways to the Sustainable Development Goals (SDGs): a comparative review of scenario modelling tools. Environ Sci Policy 66:199–207. https://www.sciencedirect.com/science/article/pii/S1462901116306712?casa_token=ZeXGgmELHJcAAAAA:RxyJ5_rXmNalCG6M6TkbXB5JbIBbU3XCt7XYsFGNCqnlBiQvsIbMNEXpLcyu-ZMsbhbXTV2qHw. Last access 28 Apr 2020

Börjeson L, Höjer M, Dreborg K-H, Ekvall T, Finnveden G (2006) Scenario types and techniques: towards a user's guide. Futures 38:723–739. https://www.sciencedirect.com/science/article/pii/S0016328705002132?casa_token=dY6OT5guCQAAAAAA:3AypMhkhVcDHaDsKS5dpk5hyhQ6KHNHhE5rMFUayow_xcYu6vLR4niKrsP9BeOMvW1Dpemgy3A. Last access 23 Apr 2020

Costanza R, Daly L, Fioramonti L, Giovannini E, Kubiszewski I, Mortensen LF, Pickett KE, Ragnarsdottir KV, de Vogli R, Wilkinson R (2016) Modelling and measuring sustainable wellbeing in connection with the UN Sustainable Development Goals. Ecol Econ 130:350–355. https://www.sciencedirect.com/science/article/pii/S0921800915303359?casa_token=3Zh_EOslGeYAAAAA:JeMuyMo-KJSE7Md7VudJMsmv7MpCBqv8zr7DitbSx1tg0eHcqk1RynW6REdovPuWlG_cMfc_wQ. Last access 29 Apr 2020

Di Comite F, Kancs D (2015) Macro-economic models for R&D and innovation policies. IPTS working papers on corporate R&D and innovation, no. 03. https://www.econstor.eu/bitstream/10419/202155/1/jrc-wp201503.pdf. Last access 23 Apr 2020

E3MLab (2014) PRIMES model 2013-2014: detailed model description. E3MLab/ICCS at National Technical University of Athens. https://ec.europa.eu/clima/sites/clima/files/strategies/analysis/models/docs/primes_model_2013-2014_en.pdf. Last access 28 Apr 2020

EC (2020) https://ec.europa.eu/clima/policies/strategies/analysis/models_en. Last access 28 Apr 2020

Ekino S, Susa M, Ninomiya T, Imamura K, Kitamura T (2007) Minamata disease revisited: an update on the acute and chronic manifestations of methyl mercury poisoning. J Neurol Sci 131–144. https://www.sciencedirect.com/science/article/pii/S0022510X07004558?casa_token=MFsOC-I0sQAAAAAA:fvW0AU33WHffOjsxGfk-8e62-LD_AwAmk6x2S77eCUWwadHQ2uIkmRnsBjdRwjMfRprsoMjLBA. Last access 23 Apr 2020

Faber A, Idenburg AM, Wilting HC (2007) Exploring techno-economic scenarios in an input-output model. Futures 39(1). https://doi.org/10.1016/j.futures.2006.03.011

Farmer JD, Foley D (2009) The economy needs agent-based modelling. Nature, Opinion vol 460/6, August. https://www.nature.com/articles/460685a. Last access 23 Apr 2020

Fleiter T, Worrell E, Eichhammer W (2011) Barriers to energy efficiency in industrial bottom-up energy demand models – a review. Renew Sust Energ Rev 15:3099–3111. https://www.sciencedirect.com/science/article/pii/S1364032111001286?casa_token=QxMzhhwKQEIAAAAA:u9XQVv_61ujv0C2TfLWvQ2SqZESmpnxKZih54WCFIno0cU2vhJmGyMNOaam-586oiyPJQV0VyA. Last access 29 Apr 2020

Glasson J, Therivel R, Chadwick A (2005) Introduction to environmental impact assessment. The natural and built environment series, 3 edn. Taylor & Francis e-library, London and New York

Gustavson KR, Lonergan SC, Ruitenbeek HJ (1999) Selection and modelling of sustainable development indicators: a case study of the Fraser River Basin, British Columbia. Ecol Econ 28:117–132. https://www.sciencedirect.com/science/article/pii/S0921800998000329?casa_token=hA3j7ZYxJAsAAAAA:4JuGZPdadww_54h4jvykg3OQvxHhXgYqj_RzMoXcpBMx8fmLP3A4AtDNNko-UOrKOzlaen3_Vw. Last access 29 Apr 2020

Hughes BB, Hossain A, Irfan MT (2004) The structure of international futures (Ifs). Working paper 2004.07.19, Pardee Center for International Futures, Josef Korbel School of International Studies, University of Denver, Denver, CO. https://pardee.du.edu/structure-international-futures-ifs. Last access 23 Apr 2020

IPCC (2014) Climate change 2014 synthesis report. IPCC fifth assessment report. https://www.ipcc.ch/report/ar5/syr/. Last access 23 Apr 2020

Laurent KL, Friedman KB, Krantzberg G, Scavia D, Creed IF (2015) Scenario analysis: an integrative and effective method for bridging disciplines and achieving a thriving Great Lakes-St. Lawrence River basin. J Great Lakes Res 41(1):12–19. https://www.sciencedirect.com/science/article/abs/pii/S0380133014002007. Last access 23 Apr 2020

Meadows DH, Meadows DL, Randers J, Behrens WW III (1972) The limits to growth: a report for the Club of Rome's project on the predicament of mankind. Universe Books, New York

Miller RE, Blair PD (2009) Input-output analysis: foundations and extensions, 2nd edn. Cambridge University Press, Cambridge

Munn RE (1977) Environmental impact assessment. In: Science for better environment: proceedings of the international congress on the human environment, Pergamon Press

OECD (2015) The economic consequences of climate change. OECD Publishing, Paris

Pruyt E (2013) Small system dynamics models for big issues: triple jump towards real-world complexity. TU Delft Library, Delft

Robertson M (2017) Sustainability principles and practice, 2nd edn. Routledge, London

Stern N (2007) The economics of climate change. Cambridge University Press, Cambridge

Sue Wing I (2004) Computable general equilibrium models and their use in economy-wide policy analysis. MIT joint program on the science and policy of global change, Technical note 6, Cambridge, MA. http://web.mit.edu/globalchange/www/MITJPSPGC_TechNote6.pdf. Last access 23 Apr 2020

UN (2014) Prototype global sustainable development report. United Nations Department of Economic and Social Affairs, Division for Sustainable Development, New York, July. https://sustainabledevelopment.un.org/globalsdreport/2014. Last access 23 Apr 2020

UN (2020). https://unfccc.int/topics/mitigation/workstreams/response-measures/modelling-tools-to-assess-the-impact-of-the-implementation-of-response-measures/responses-measures-models-gem-e3. Last access 28 Apr 2020

UNECE (2016) Protocol on strategic environmental assessment: facts and benefits. http://www.unece.org/fileadmin/DAM/env/eia/Publications/2016/Protocol_on_SEA/1609217_UNECE_HR.pdf. Last access 23 Apr 2020

UNEP (2002) Environmental impact assessment training resource manual, 2nd edn, eds. Sadler B, McCabe M. Geneva. https://unep.ch/etb/publications/EIAman/IntroManual.pdf. Last access 23 Apr 2020

UNEP (2004) Global environment outlook scenario framework. Background paper for UNEP's third global environment outlook report (GEO-3). https://www.unenvironment.org/resources/report/global-environment-outlook-scenario-framework-background-paper-uneps-third-global. Last access 23 Apr 2020

UNEP (2019) Global Environment Outlook – GEO-6: healthy planet, healthy people, ed. Ekins P, Gupta J, Boileau P. Cambridge University Press. https://wedocs.unep.org/bitstream/handle/20.500.11822/27539/GEO6_2019.pdf?sequence=1&isAllowed=y. Last access 29 Apr 2020

United Nations (2014) Prototype global Sustainable Development Report. United Nations Department of

Economic and Social Affairs, Division for Sustainable Development, New York, July 2014. https://sustainabledevelopment.un.org/globalsdreport/2014. Last access 23 Apr 2020

Van Notten P (2006) Scenario development: a typology of approaches, chapter 4. In: Think scenarios, rethinking education. OECD. http://www.oecd.org/site/schoolingfortomorrowknowledgebase/futuresthinking/scenarios/37246431.pdf. Last access 23 Apr 2020

Vincenot CE, Mazzoleni S, Parrott L (eds) (2016) Hybrid solutions for the modelling of complex environmental systems. Frontiers Media, Lausanne

Walz A, Lardelli C, Behrendt H, Grêt-Regamey A, Lundström C, Kytzia S, Bebi P (2007) Participatory scenario analysis for integrated regional modelling. Landsc Urban Plan 81:114–131. https://www.sciencedirect.com/science/article/pii/S0169204606002398?casa_token=_7115HZCDPIAAAAA:gQjInUZTVL4LZaLC_7HhtqFTrugaHziE4ACW2bLQKhMHqWakC-KAWciuW7dD8fiBEY44UMOOZg. Last access 23 Apr 2020

Wellman J, Hunt A (2016) Methods for the assessment of systemic change. Deliverable 3.3. EC DG Research ECONADAPT Project. Grant agreement no 603906. https://econadapt.eu/sites/default/files/docs/Deliverable-3.3-approved.pdf. Last access 28 Apr 2020

Worrell E, Price L (2001) Policy scenarios for energy efficiency improvement in industry. Energy Policy 1223–1241. https://www.sciencedirect.com/science/article/abs/pii/S0301421501000696. Last access 28 Apr 2020

Zagamé P, Boitier B, Fougeyrollas A, Le Mouel P (n.d.) The NEMESIS reference manual. www.erasme-team.eu, http://www.erasme-team.eu/files/Manual_Part_I.pdf. Last access 28 Apr 2020