ENVIRONMENTAL SCIENCE & POLICY 47 (2015) 148–156

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/envsci

In silico science for climate policy: How policy-makers process and use carbon storage simulation data

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ARTICLE INFO

Keywords:
Simulation and modeling
Geosciences
Carbon capture and storage
Science–policy interface

ABSTRACT

Knowledge gained from computer simulations in new earth-related technologies is not limited to the scientific community itself but impacts other domains of society such as politics, business and industry, and the public at large. In general business and industry in the oil and gas business are using computer simulations on a daily basis. In this case it is using computer simulations to gain understanding of the risk of a new technology which would affect the subsurface on a large scale and hence in Europe a substantial amount of people. So far, research did not consider in depth patterns of *in silico* science for policy. This paper analyses how policy-makers process and use simulation data based on a case-study of geo-scientific carbon dioxide capture modeling. The empirical results are based on 19 qualitative interviews with decision-makers from politics, business and industry, and society. The empirical results reveal a great variety of co-existing perception, evaluation and use patterns of how decision-makers deal with simulations. The field work reveals that the current state-of-the-art in research literature which emphasizes an overall misperception, misunderstanding and misuse of simulation data by policy-makers is, in general, not backed by the case-study results. However, scientific simulations do leave considerable room for misunderstandings for experts not disposing on specific geo-scientific and simulation expertise.

1. Introduction

Computer simulations have been established as a fundamental instrument in the field of information and communication technologies and play a major role in scientific knowledge production. Scientific knowledge gained from computer simulations in new earth-related technologies is not limited to the scientific community itself but impacts other domains of society such as politics, business and industry, and the public at large. In general business and industry in the oil and gas business are using computer simulations on a daily basis. In this case it is using computer simulations to gain understanding of the risk of a new technology which would affect the subsurface on a large scale and hence in Europe a substantial amount of people. Impacting societal domains, simulations meet two principal functions: they serve as a knowledge instrument as well as a communication instrument at the science–policy

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http://dx.doi.org/10.1016/j.envsci.2014.11.008
1462-9011/

interface. Nonetheless, so far science did not consider in depth how processes and circumstances of simulations-based knowledge transfer works. Hence, this study analyses how scientific simulation results are processed by policy-makers using a case study of geo-scientific carbon dioxide storage modeling. The paper builds on research carried out as part of a PhD thesis (Scheer, 2013).

The case study centers on dynamic geologic simulations as used for computer representations (of portions) of the subsurface. According to Mallet (2002: 4) geo-scientific modeling consists of the set of all the mathematical methods allowing to model in an unified way the topology, the geometry and the physical properties of geological objects while taking into account any type of data related to these objects. A simulation can be defined as the computerized imitation of the operation of a real-world process or system over time (Banks, 1998: 3). Although geo-scientific modeling contains strictly two subsequent steps with first building the structural geological model and second running computerized processes over time within the structural model, both terms are used quite often synonymously in geosciences literature. I follow this tradition and use both terms interchangeably.

Existing geo-scientific modeling is adequate for several subsurface resource recoveries such as oil and gas production or groundwater management, but is currently seen to be not sufficient for areas such as nuclear waste disposal or carbon storage. This is due to the fact that ‘‘current practice in inverse modeling tends to decouple processes, to aggregate parameters across scales, and to include only a limited amount of the available, real data’’ (US DOE, 2007: 57). Current shortcomings relate first to the importance of coupled processes in hydrothermal systems, which denote the interplay of fluid flow, solute transport, heat transfer, and chemical and mechanical interactions between rocks and fluids. Second to the presence of structures and interactions on a vast range of space and time scales, that are not compatible with space and time resolution of the models (US DOE, 2007: 50; Gessner et al., 2009). In the field of geo-scientific carbon dioxide storage modeling is primarily used for characterization of potential CO_2 storage reservoirs, and to secure CO_2 storage containment and safety over different time scales. Considering the mentioned shortcomings, efforts are needed to develop modeling capabilities for subsurface processes across multiple space and time scales to evaluate hazards and risks that may be associated with the design, operation and monitoring of storage facilities and operations (IPCC, 2005; US DOE, 2007). However, geo-scientific carbon dioxide storage modeling also meet some principle constraints as pointed out by Oreskes et al. (1994). To their opinion verification and validation of numerical models of natural systems is impossible because natural systems are never closed and model results are always non-unique. This conclusion is most relevant for *in silico* science for policy since simulation results are used to prepare policy options and justify policy decision.

Thorngate and Tavakoli (2009: 514) stated no meta-studies or literature overviews on simulations impacting policy-making are available. In fact, there is a lack of synthesizing the great variety of existing case studies and policy field related research. However, within the last decade or so a considerable amount of research tackled the issue of simulation at the science–policy interface. Literature reveals several functions simulations might take over in policy-making (van Daalen et al., 2002; Fisher et al., 2010; Farber, 2008; NRC, 2007; van der Sluijs et al., 2008). van Daalen et al. (2002), for instance, identified four types: models serve as eye-openers in placing new environmental issues on the political agenda. Models play an advocative role as arguments in dissent where they challenge opposing assessments. Thirdly, models help as a vehicle to create consensus among different stakeholders. Finally models for management support identifying concrete policy decision and assessing effects of the implementation of policies.

The body of literature largely emphasizes problems of perception, credibility and misuse by decision-makers resulting in deficient policies. Van der Sluijs (2002) identify a ‘‘credibility crisis of models used in integrated environmental assessments’’. Brugnach et al. (2007: 1075) state a lack of acceptance for computer simulations among policy-makers while Fisher et al. (2010: 251) argue, that ‘‘[l]awyers and policy-makers have overlooked models and not engaged critically with them’’. Finally, Wagner et al. (2010: 293) observe a fundamental and systematic misperception among political decision-makers when they state: ‘‘computational models are fundamental to environmental regulation, yet their capabilities tend to be misunderstood by policymakers’’ (Wagner et al., 2010: 293).

Deficits identified highlight both aspects of the simulation tool itself and people dealing with them. Simulation-based deficits stress (missing) quality aspects of models concluding that weak policy impact is due to not adequately communicate model uncertainty and complexity (Hellström, 1996; Ivanović and Freer, 2009; Petersen, 2006). In addition, epistemic constraints and limitations of simulations are claimed since they are not able to match adequately with reality (King and Kraemer, 1993; Oreskes, 2000; Pilkey and Pilkey-Jarvis, 2007). Consequently, policy-makers perceive models as opaque not able to interpret simulation data in the intended way (Olsson and Anderson, 2007; Policy Foresight Programme, 2008; Wagner et al., 2010). Contextual deficits accounts are even more heterogeneous. First, on a macro level scholars argue with disparate modes of operation of the science and politics system yielding to distinct system behavior (Haag and Kaupenjohann, 2001). Second, model knowledge deficits among policy-makers and the subjectivity of modelers are claimed to be relevant while thirdly hardly any exchange between both groups is observed (Walker et al., 2003; Fine and Owen, 2005). Taking these shortcomings of simulations at the science–policy interface altogether several scholars conclude a fundamental misunderstanding and misuse of models in policy-making (Fisher et al., 2010; Wagner et al., 2010).

Based on these shortcomings several scholars dealt with developing tools, guidelines and recommendations for improving the use of simulations (Boulanger and Bréchet, 2005). This includes encouraging cooperation between modelers and decision-makers (e.g. Alcamo et al., 1996), developing evaluation tools for adequate model selection (e.g. Brenner and Werker, 2009; Yücel and van Daalen, 2009) and innovating in methods for enhancing transparency and involvement of stakeholders along the modeling process (e.g. Schmolke et al., 2010). For a more extensive review of literature, see Scheer (2013).

To sum up, findings from literature seem to be clear. To put it bluntly: in principle, there is hardly any perception of