Ecological Economics 111 (2015) 29–47

Contents lists available at ScienceDirect

Ecological Economics

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

Analysis

Dynamics of energy transitions under changing socioeconomic, technological and climate conditions in Northwest Germany

Matthias Ruth [a,*], Onur Özgün [a], Jakob Wachsmuth [b], Stefan Gößling-Reisemann [b]

[a] School of Public Policy and Urban Affairs, Northeastern University, 360 Huntington Ave., Boston, MA 02115, USA
[b] Research Center for Sustainability Studies (Artec), University of Bremen, Enrique-Schmidt-Str. 7, 28359 Bremen, Germany

ARTICLE INFO

Article history:
Received 11 May 2014
Received in revised form 5 November 2014
Accepted 31 December 2014
Available online 24 January 2015

Keywords:
Regional integrated assessment
Energy transitions
Renewable energy
Regional development
Stakeholder engagement
Simulation modeling

ABSTRACT

This paper analyzes regional interdependencies and trajectories of the energy and agriculture sectors in Germany's Northwest Metropolitan Region in order to assess the performance of regional low-cost and low-carbon strategies to alter energy sector profiles in the light of changing socioeconomic, technological and climate conditions. Our assessment is based on a dynamic, interactive simulation model for the years 2010 to 2050, which was developed and played out in close collaboration with diverse stakeholder groups in the region. Results from the model and modeling exercises demonstrate the need to increase energy efficiency because the reduction in demand it generates extends the policy space for decreasing emissions and reduces vulnerability to climate change. The results also show the feasibility of expanding renewable energy without heavy reliance on biomass, which currently is an important and contested source of energy in the region.

1. Introduction

Demographic, technological, economic and environmental changes often come together in ways that can overwhelm decision makers in their quest for strategies that ensure long-term prosperity and quality of life. Policies and investments implemented in one region or for one sector of the economy likely result in impacts on other regions and sectors, and thus alter the broader context within which everyone must operate. Promotion of biomass as an energy source, for instance, will trigger changes in crop mix and thus input requirements and environmental performance of the agricultural sector (Koonin, 2006). Changes in outputs from agriculture, in turn, are likely accompanied by differences in energy demand for processing, cooling and shipments of food products. At the same time, biomass production and energy demand are both affected by climate change, which will adversely affect agricultural productivity, increase cooling demand, and threaten the reliability of electricity generation and distribution.

Given Germany's push towards renewable fuels and potential exposures of its regions to climate change, questions arise how to identify decisions that make good sense at the regional level under a wide range of future conditions, many of which are unknown or unknowable today. Regional decision makers are thus confronted with many dimensions of uncertainty and conflicting goals. In this paper we showcase the application of a regional dynamic, interactive simulation model to the interdependencies and trajectories of the energy and agriculture sectors of the Bremen/Oldenburg Metropolitan Region in Northwest Germany. That model has three main purposes: (1) provision of a structured platform for data organization and dialog with stakeholders for joint knowledge production (Hegger et al., 2012); (2) exploration of a wide range of what-if scenarios in preparation of investment and policy making; and (3) recursive (adaptive) planning where the results of past actions are assessed within an ever-changing socioeconomic, technological and environmental context to guide future action (Gunderson, 1999; Folke et al., 2005).

The term resilience, as used in this project, draws on definitions from ecosystem and social–ecological systems theory (Holling, 1973; Folke et al., 2004; Holling and Gunderson, 2002; Brand, 2005) and describes the capability of systems to maintain their system services (e.g. agriculture and food production, energy provision, regional governance) in turbulent environments. Our vulnerability assessment explores climate change impacts and structural system weaknesses that could lead to restrictions or failures of system services (Gößling-Reisemann et al., 2013) in the case of external and internal stress (Stührmann et al., 2012).

The dynamic model and its uses by stakeholders enable us to identify options to address a set of challenges that may be slow or fast compared to the system's own rate of change, and that depend on experience with both the challenges and the options to address them (Table 1): A resilient system that is exposed to a slowly developing change in the environment which it has already experienced in the past, needs to adapt its existing elements and mechanisms to that

* Corresponding author.

http://dx.doi.org/10.1016/j.ecolecon.2014.12.025
0921-8009/

Table 1
General challenge categories and needed capabilities of a resilient system.

Challenge categories	Known	Unknown
Slow/creeping	Adaptive capacity	Innovation capacity
Fast/sudden	Robustness	Improvisation capacity

change. If the challenge is new to the system, it is very likely that new elements and mechanisms will have to be developed; thus innovation capacity is needed. For challenges developing fast, but which are already known to the system, robustness can be (and usually is) built into existing infrastructures and institutions. For challenges that develop fast and have never been experienced by the system, there is no time for preparing the current system with adaptive, innovative or robust components. Coping with such challenges has to rely on improvisation by rearranging existing elements and mechanisms.

Irrespective of the type of challenge, scarce resources have to be made available to improve resilience. Running the model with stakeholders under a wide range of conditions that are a priori unknown to them allows for the ex post identification of resources and actions that should have been deployed to reduce vulnerabilities and improve resilience — knowledge that can be carried forward to future periods or successive model runs and that is beginning to inform real-world decision making in the region.

Regional integrated assessments related to the one presented here have recently found wide application in tackling climate change challenges, such as in agriculture (Fischer et al., 2005), natural resource management (Krol and Bronstert, 2007) or land use (Holman et al., 2005). Being based on multi-disciplinary insights, spatially aware, and dynamic, these models are increasingly capable of synthesizing disparate knowledge and providing practical guidance towards regional adaptation (e.g. Wenkel et al., 2013; Köstner et al., 2013). By involving stakeholders at various stages of the process from problem formulation to analysis, participatory integrated assessment models aim to increase the quality of environmental and sustainability decisions (Pahl-Wostl et al., 2000; Holman et al., 2005; Cohen et al., 2006; Patel et al., 2007; Salter et al., 2010).

Our approach to explore future behaviors of the region builds on experiences with regional integrated assessments, but distinguishes itself from them in two main ways. First, regional resilience is usually identified by simulating a system under different conditions and by deciding what the stability thresholds are. However, system behavior is a result of policies and decision making by human actors, and this decision making process is treated too simplistically or even ignored by simulation models (Duke and Geurts, 2004; Mayer, 2009). An alternative is to engage stakeholders in devising policies. However this can result in “negotiated nonsense” if there is no validation using real world data and system behavior. Thus, we designed our model to be run interactively by actual stakeholders to make choices in a validated environment. Involving regional stakeholders as players of the model can have immediate impact on investment and policy making because they learn from interacting with the simulation model and from other actors (Voinov and Bousquet, 2010; Reed, 2008; Conde et al., 2005), and because they are confronted with systems implications of their decisions that are felt outside their usual decision making realm.

This leads to the second feature that differentiates our approach from other regional integrated assessments. Since decision-making does not happen unilaterally or in a social vacuum, we deploy a participatory multi-actor approach, where players in the game come from the various decision making realms of the region — private firms, government agencies, trade organizations, engaged citizens, and the like. By interacting with each other, and experiencing the ramifications of decisions, the tensions, trade-offs, and compromises among actors become apparent in the face of climate change and other socioeconomic and technological drivers, which can help them determine desirable policies and process management designs (de Bruijn et al., 2010).

The following section provides a brief overview of the region in which we have deployed the multi-actor integrated assessment model (MAIA). Section 3 lays out the main structure of the model and its workings. Sections 4 and 5 describe, respectively, the broader socioeconomic, environmental and political contexts within which the model operates, and the region-specific strategies that may be chosen to guide decisions. Section 6 presents the results, and Section 7 closes the paper with a focus on the insights the model and stakeholder interaction have generated for the creation of strategies geared towards regional resilience to climate change.

2. Regional Background

The European Metropolitan Region of Bremen/Oldenburg (Metropole Nordwest) is one of eleven metropolitan regions of Germany (Fig. 1). Uniting the city–state Bremen with the surrounding cities and counties in the state of Lower Saxony, the metropolitan region is composed of eleven rural counties and five core cities: Bremen, Oldenburg, Bremerhaven, Delmenhorst and Wilhelmshaven. In 2010, total population slightly exceeded 2.7 million, and per capita GDP was at € 28,514 below the average of € 30,294 in Germany.

The region has long been a center of the shipping and logistics industry, for food production, and hosts expertise in aerospace, energy and environmental technology (Metropolregion, 2008). Value added from the agricultural sector, including forestry and fisheries, as a percentage of total value added in the region was 1.7%, compared to 0.8% in Germany as a whole. Regional manufacturing accounted for 23.6% of value added (24.7% in Germany) and services for 62.2% (70.1% in Germany).

Given the coastal location of the region, climate change impacts – particularly those from sea level rise – have long been a concern to planners and decision makers (Schuchardt and Schirmer, 2005). In recent years, climate change mitigation-related concerns have begun to permeate virtually all sectors. With aggressive movement towards an energy sector based on renewable sources – accelerated by recent political developments in Germany to move away from fossils and nuclear power (BMWi and BMU, 2010) – the use of wind, photovoltaics and biogas plants to generate electricity has expanded. However, the current fuel mix is still dominated by fossil fuels. In 2009, shortly before the German government decided to abandon nuclear power and substantially increase the renewable energy share, coal, natural gas, and oil powered plants dominated, at 42%, the total installed capacity of 5770 MW in the region. Coal power plants (1641 MW) as the predominant fossil fuel power generation technology, were followed by natural gas (approximately 700 MW), and further generation from a variety of sources, such as wind, photovoltaics, biomass, landfill gas blast furnace gas, household waste, medium calorific wastes, and sewage. The nuclear power plant has been shut down in the meantime, while photovoltaics, wind and biomass have grown markedly in recent years, without replacing fossil fuels as the major source for electricity generation. The heating and transport energy demand is almost fully met by fossil fuels.

A shift in power generation from conventional sources to renewables will not only challenge the reliability of power supply, especially during peak demand periods, but also be controversial in counties where cropland is lost from food production. Land-use conflicts are already a major concern in the area, given its long standing as a rich agricultural economy that produces crops, pork, dairy and poultry products. In 2010, nearly 14,000 agricultural enterprises produced on over 840,000 ha of land, with 64% of that land being used to produce wheat, barley, potatoes, beets, rapeseed and corn. Energy crops, primarily corn, required an estimated 40,000 ha of land. The remaining 36% of farmland was classified as pasture, providing fodder for around 1.2 million cattle. Also, in that year, over 4.6 million pigs and almost 30 million chickens and hens were raised in the region.

Given existing economic structures, the expansion of energy crops has become highly controversial in counties where cropland is lost