Cities and Climate Change: A Simulation Model for the Ruhr Area 2050

Felix Huber, Klaus Spiekermann, Michael Wegener

(Univ.-Prof. Dr.-Ing. Felix Huber, Bergische Universität Wuppertal, huber@uni-wuppertal.de)
(Dr.-Ing. Klaus Spiekermann, Spiekermann & Wegener, Dortmund, ks@spiekermann-wegener.de)
(Prof. Dr.-Ing. Michael Wegener, Spiekermann & Wegener, Dortmund, mw@spiekermann-wegener.de)

1 ABSTRACT

Cities are the largest emitters of greenhouse gases through heating, air conditioning, manufacturing and transport and because of their high density particularly vulnerable to impacts of climate change like floods, droughts, storms or heat waves. Cities therefore play a central role in mitigation of and adaptation to climate change. However, current policy responses tend to focus on small-scale adaptation measures and to ignore more radical, less popular policies to achieve the climate protection objectives of the Federal Government and the European Union.

With a population of more than five million, the Ruhr area is one of the largest urban agglomerations in Europe. Through its industrial past and polycentric urban system it has the potential for spatial development with little land consumption, small energy use and short travel distances. To explore the long-term options for mitigation of and adaptation to climate change in the Ruhr area, an existing simulation model of urban land use, mobility and environment is being extended to explore the impacts of policies from the fields of land use and transport planning on greenhouse gas emissions, the environment, economy, mobility and quality of life in the Ruhr area. The paper presents the model under development.

2 INTRODUCTION

Twenty percent of mankind command eighty percent of the world's wealth and are responsible for eighty percent of energy use and greenhouse gas emissions. This inequality is growing. Since the 1970s, the per-capita income of the industrialised countries has grown by a factor of ten, whereas that of the developing countries has only tripled. But another multiplication of production, consumption and resource use of the rich countries as in the last thirty years would exceed the resources of the earth. Today it is foreseeable that if the energy consumption of the world continues to grow as in the past, the known deposits of fossil fuels will be exhausted before the end of this century. If, however, one adds the growing energy demands of Brazil, China, India and Russia, they will already be depleted in a few decades.

However, only few politicians and scientists are seriously taking account of this situation. Only few countries meet the target set by the United Nations to spend 0.7 percent of their national product on development aid. Mainstream neo-liberal economic theory continues to put its stakes on further deregulation of international trade and unconstrained economic growth. There are virtually no theories, concepts or visions of how a sustainable economic order might be developed without continued material growth in the richest countries.

Warning signals that the era of unlimted growth is about to end are mounting. In July of 2008 the price of crude oil rose to almost 150 US $ per barrel. During the recent world-wide financial and economic crisis it went back to below 40 US $ per barrel and has since risen again to more than 100 US $. Most experts believe that, because of the final depletion of oil resources, of political instability in the Middle East and of rising demand of fast growing developing countries, oil will continue to become more expensive. Similar trends are to be expected for other raw materials.

Closely related to this are the challenges of climate change. Climate researchers agree that anthropogenic greenhouse gas emissions contribute significantly to global warming and that to avoid the worst implications of global warming a reduction of greenhouse gas emissions by fifty percent world-wide is necessary. The question is how this reduction is to be achieved. To demand that all countries equally reduce their greenhouse gas emissions, would prevent the least developed countries from advancing their economies. Figure 1 shows CO_2 emissions per capita per year in 1990 and 2007 compared to the CO_2 emissions considered as climate-neutral (2 t per capita per year). It becomes apparent that countries like the United States or Canada need to reduce their CO_2 emissions by 90 percent, most European countries by 80 percent and China by 50 percent in order to allow developing countries like India, Bangladesh or Rwanda to catch up in economic development.

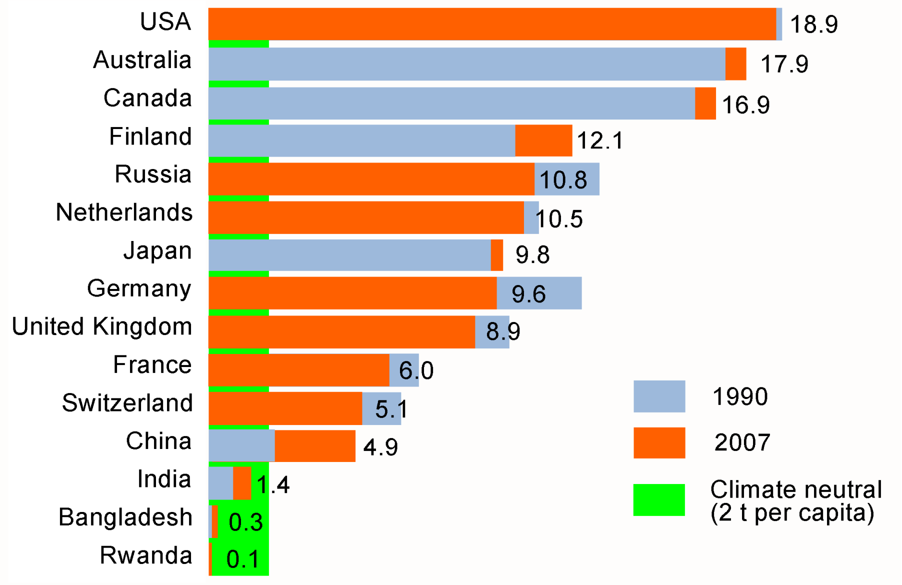

Figure 1 CO_2 emissions per capita per year (t) 1990-2007 (CDIAC, 2010)

The growing awareness of the seriousness of the challenge has led to the proclamation of ambitious greenhouse gas emission targets. In March 2007, the EU heads of state signed a resolution to achieve 20 percent less energy consumption, 20 percent renewable energy and 20 percent less CO_2 emissions compared to 1990 by 2020, and 30 percent less CO_2 emissions if other industrial countries join. In August 2007 the German government adopted the goal to reduce CO_2 emissions by 40 percent until 2020. At the G8 summit in L'Aquila in 2009 the EU joined the resolution that the industrialised countries of the world need to reduce their greenhouse gas emissions by 80 percent until 2050 compared to 1990. To achieve these targets will have significant consequences for the spatial development of regions and cities in Europe.

3 OBJECTIVES

The proposed project aims at the development and application of an integrated model system to assess and evaluate the impacts of policies to mitigate climate change and to adapt to impacts of climate changes no longer avoidable in urban regions using the Ruhr area as a case study region.

The Ruhr area is of particular interest as a case study region. With a population of more than five million, it is one of the largest urban agglomerations in Europe but lacks a singular dominant metropolitan centre. Through its industrial past and its historically grown polycentric urban system it has a particular potential to convert former industrial sites to high density, mixed-used developments with little land consumption, small energy use and short travel distances.

Current policy responses to climate change focus on small-scale measures of adaptation to impacts of climate change no longer avoidable and tend to ignore necessary measures to mitigate still avoidable climate change and achieve the climate protection objectives of the Federal Government and the European Union. A notable exception is the InnovationCity Ruhr, an ambitious project of major industrial companies of the Ruhr area to develop a low-carbon model city in Bottrop in the western Ruhr area (Iniativkreis Ruhr, 2011).

In the proposed project a simulation model of urban land use, mobility and environment developed at the Institute of Spatial Planning of the University of Dortmund is to be extended to predict the impacts of policies for the mitigation of and the adaptation to climate change from the fields of land use and transport planning on the environment, economy, mobility and quality of life in all cities of the Ruhr area until 2050. The model is to be used to simulate and evaluate spatial scenarios which differ in their assumptions about avoidable and unavoidable climate changes and the effects on spatial structures, on the economic conditions of households as well as on traffic and transport by possible combinations of policies to achieve the climate protection targets of the Federal Government and the European Union and to adapt the region to no longer avoidable climate changes.

4 STATE OF THE ART

The foreseeable impacts of climate change are a topic of research since the 1970s. Already in 1992, before the United Nations Conference on Environment and Development in Rio de Janeiro, the Federal Government established the Scientific Council for Global Environmental Change (WBGU). In the same year the Potsdam Institute for Climate Impact Research (PIK) was founded. With the United Nations Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change of 2007 (IPCC, 2007) a wider public became aware that significant climate changes and their impacts, such as floods, storms or heat waves are no longer avoidable. And it has become obvious that for the mitigation of even worse impacts the emissions of greenhouse gases in the richest countries of the world need to be reduced by 80 percent.

The consequence of this change of awareness has been a growth in scientific attention also for the spatial impacts of climate change. There exist now numerous studies on the impacts of different climate scenarios on regional risks of floods, heat waves or changes in vegetation and biodiversity (EEA, 2003; UBA, 2005; UBA/PIK, 2005; ESPON 1.3.1, 2006; BMU, 2007; Beierkuhnlein und Foken, 2008; BUND, 2008; Heiland et al., 2008; IfR, 2008). There are also first studies about possible measures to adapt to these changes, mostly in the form of policy recommendations (Baumüller et al., 1993; UBA/PIK, 2005; Fleischhauer and Bornefeld, 2006; ARL, 2007; Ritter, 2007; Bartolomew et al., 2007; BMU, 2007; European Commission, 2007; Stern et al., 2006; BUND, 2008; IfR, 2008; MUNLV, 2010; Stadt Dortmund, 2011).

However, only few of these policy recommendations are addressed to cities, and these are usually limited to recommendations for short-term adaptation measures. Mitigation policies tend to be treated only in general terms. What is missing are impact analyses and forecasts which – as far as possible with present knowledge – quantify the likely impacts of the proposed and other policies from the fields of land use and transport planning on the reduction of energy consumption and greenhouse gas emissions and the impacts of unavoidable climate change and the price in terms of necessary investments and losses in consumption and mobility that would have to be paid. Also missing are forecasts of possible indirect impacts, such as positive or negative synergies of different types of policies, such as fiscal, legal or planning policies, i.e. whether policies reinforce, complement, substitute or counteract each other.

Other European countries are more advanced in this respect. One example for this is the Cities Programme of the Tyndall Centre for Climate Change Research in the United Kingdom (Dawson et al., 2009). The objective of the programme is to develop a model system to simulate the impacts of climate change in cities and compare alternative mitigation and adaptation measures. The *Urban Integrated Assessment Framework* under development will predict the analysis of mitigation and adaptation measures, such as taxes, fees, emission permits, high-density mixed-used developments, land use restrictions, infrastructure investments, alternative fuels, travel demand management, flood retention basins, heat insulation of buildings and more energy-efficient vehicles in a unified model framework.

5 THE MODEL

The model to be used in the planned project is the integrated land-use and transport model developed at the Institute of Spatial Planning of the University of Dortmund (Wegener, 2001) and has been applied in many EU and national projects, such as PROPOLIS (Lautso et al., 2004), ILS NRW (2005), STEPs (Fiorello et al., 2006) and Huber et al. (2007). The model contains submodels of household development, public and private construction, the regional labour and housing markets and a detailed regional transport model. It predicts for each simulation period intraregional location decisions of industry, residential developers and households, the resulting migration and travel patterns, construction activity and land use development and the impacts of public policies in the fields of industrial development, housing, public facilities and transport.

The present study area of the IRPUD model is the urban region of Dortmund in the eastern Ruhr area with a population of 2.3 million. The study area of the planned project will be the whole Ruhr area, i.e. the territory of the Regional Association Ruhr (RVR). Figure 2 shows the present study area, the eastern Ruhr area (in yellow) and the planned study area, the territory of the Regional Association Ruhr (in grey). For modelling land use and transport in the extended study area, the study area will be subdivided into about 600 zones and for the environment models into raster cells of 100x100 m size. A larger area including major parts of North Rhine-Westphalia will be considered as external zones.

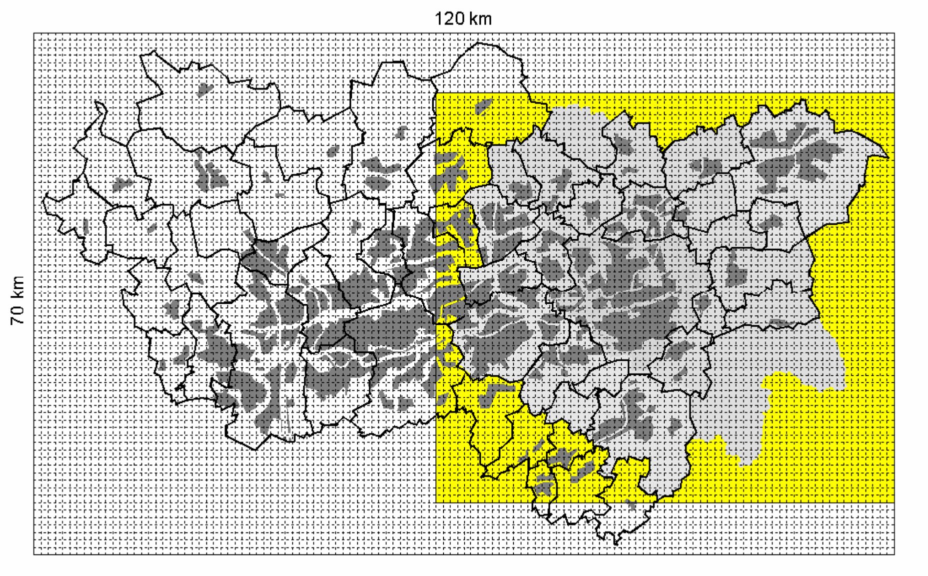

Fig. 2: Study area: the Ruhr area.

The IRPUD model will be integrated with high-resolution submodels of environmental impacts of land use and transport so that it predicts not only environmental impacts but also their effects on the location decisions of households and firms. The environmental impact submodels needed are partly already available (air quality, traffic noise, biodiversity), and will partly have to be developed (building energy, process energy, solar energy and wind energy, floods, heat waves). Figure 3 summarises the interactions between the urban environment and urban land use and transport classified under the headings of *resources*, *emissions* and *exposure* (Spiekermann and Wegener, 2008).

Cause				Resources						Emissions						Exposure			
	Effect	Land use	Transport	Energy	Water	Land	Vegetation	Wildlife	Microclimate	Greenhouse gases	Air pollution	Water pollution	Soil contamination	Solid waste	Noise	Air quality	Surface water flows	Ground water flows	Noise propagation
Land use		●	●	●	●	●	●	●	●	●	●	○	●	●	●	●	●	●	●
Transport		●	●	●		●	○	○		●	●	○	○	○	●	●			●
Energy	Resources	○	○	●						●	●					●			
Water	Resources				●												●	●	
Land	Resources	●			●	●	●	●	●								●	●	○
Vegetation	Resources	○			○		●	●	●	●									●
Wildlife	Resources							●											
Microclimate	Resources	○					○	○	●										
Greenhouse gases	Emissions									●									
Air pollution	Emissions								●		●					●			
Water pollution	Emissions				●		●	●				●					●	●	
Soil contamination	Emissions	○				●	●	●				●	●						
Solid waste	Emissions	○			○	○							●	●			●	●	
Noise	Emissions														●				●
Air quality	Exposure	●					●	○	●			○	○			●			
Surface water flows	Exposure				●		●	●	●								●		●
Ground water flows	Exposure				●		●	●	●									●	
Noise propagation	Exposure	●						●											●

○ weak impact ● strong impact

Fig. 3: Interactions between urban land use, transport and the environment.

For the new environmental model components data about water, topography, wind, buildings, land coverage and vegetation will be required. The extension of the model to include the whole Ruhr area will require data about households, residential and non-residential buildings, public education and health facilities and transport networks also for the western part of the Ruhr area. The extended transport network data are already available from another research project (STB, 2011). Based on the extended network data a prototype of the extened transport submodel is already operational.

The model system will then be applied to simulate spatial scenarios. The scenarios will differ by their assumptions about climate change and the resulting impacts as well as possible combinations of European, national, regional and local measures to mitigate climate change and to adapt the region to no longer avoidable impacts of climate change. A simulation scenario will be a combination of a regional climate scenario with one or more policies from the fields of economic promotion, land use planning, infrastructure investment, transport planning, or policies to internalise external costs of energy consumption, such as a carbon tax, fuel taxes or road pricing.

Target year of the simulations will be the year 2050. The model will produce for each scenario and for each year of the simulation detailed information about the spatial development of population, work places, land use and buildings, the number of trips by travel time, distance and mode and environmental impacts in terms of energy consumption, greenhouse gas emissions, air quality, traffic noise, loss of open space and biodiversity, flood risk and heat islands.

6 RESULTS

The project will give answers to the following questions:

- What would be the impacts of regional climate scenarios for the Ruhr area without mitigation and adaptation measures on environment, economy, mobility and quality of life in the Ruhr area?
- What would be the impacts of fiscal, legal, and planning mitigation and adaptation policies at European, national, regional and local level on environment, economy, mobility and quality of life in the Ruhr area?
- Which positive and negative synergies would exist between fiscal, legal and planning measures at European, national, regional and local level, if these measures were combined in integrated strategies?
- Which integrated strategies need to be implemented at European, national, regional and local level to achieve the climate protection targets of the Federal Government and the European Union?

The results of selected scenarios will be presented in easy to understand visual form and used to formulate recommendations for policy action.

7 REFERENCES

ARL – AKADEMIE FÜR RAUMFORSCHUNG UND LANDESPLANUNG: Europäische Strategien der Anpassung an die Folgen des Klimawandels: die Sicht der Raumplanung. Positionspapier 73. Hannover: ARL, 2007.

BARTHOLOMEW, K., CHEN, D.T., EWING, R., WALTERS, J., WINKELMAN, S.: Growing Cooler: The Evidence on Urban Development and Climate Change. Washington, DC: The Urban Land Institute and Smart Growth America, 2007. http://www.smartgrowthamerica.org/gcindex.html.

BAUMÜLLER, J., HOFFMANN, U., REUTER, U.: Städtebauliche Klimafibel. Hinweise für die Bauleitplanung. Stuttgart: Innenministerium Baden-Württemberg, 1993. www.staedtebauliche-klimafibel.de.

BEIERKUHNLEIN, C., FOKEN, T.: Klimawandel in Bayern. Auswirkungen und Anpassungsmöglichkeiten. Bayreuther Forum Ökologie 113, 2008.

BMU – BUNDESMINISTERIUM FÜR UMWELT, NATURSCHUTZ UND REAKTORSICHERHEIT: Klimawandel in den Alpen. Fakten – Folgen – Anpassung. Berlin: BMU, 2007.

BUND – BUND FÜR UMWELT UND NATURSCHUTZ UND BROT FÜR DIE WELT, EVANGELISCHER ENTWICKLUNGSDIENST: Zukunftsfähiges Deutschland in einer globalisierten Welt: Eine Studie des Wuppertal Instituts für Klima, Umwelt, Energie. Frankfurt: Fischer Taschenbuch Verlag, 2008.

CDIAC – Carbon Dioxide Information Center. Fossil-Fuel CO_2 Emissions. Oak Ridge National Laboratory, Oak Ridge, TN, 2010. http://en.wikipedia.org/wiki/List_of_countries_by_ carbon_dioxide_emissions_per_capita

DAWSON, R. J., HALL, J. W., BARR, S. L., BATTY, M., BRISTOW, A. L., CARNEY, S., DAGOUMAS, A., EVANS, S., FORD, A., HARWATT, H., KÖHLER, J., TIGHT, M. R., WALSH, C. L. AND ZANNI, A. M. A Blueprint for the Integrated Assessment of Climate Change in Cities. Working Paper 129. Newcastle upon Tyne: Tyndall Centre for Climate Change Research, 2009. http://www.tyndall.ac.uk/sites/default/files/wp129.pdf.

EUROPEAN COMMISSION: Green Paper Adapting to Climate Change – Options for EU Action. COM(2007) 354 final. Brussels: Commission of the European Communitiues, 2007. http://eur-lex.europa.eu/LexUriServ/site/en/com/2007/com2007_ 0354en01.pdf.

EEA – EUROPEAN ENVIRONMENTAL AGENCY: An Inventory of Biodiversity Indicators in Europe, 2002. Technical Report 92. Copenhagen: EEA, 2003.

ESPON 1.3.1: Spatial Effects of Natural and Technological Hazards. Final Report. Luxemburg: ESPON, 2006. http://www.espon.eu/export/sites/default/Documents/Projects/ESPON2006Projects/ThematicProjects/NaturalHazards/fr-1.3.1_revised-full.pdf.

FLEISCHHAUER, M., BORNEFELD, B.: Klimawandel und Raumplanung – Ansatzpunkte der Raumordnung und Bauleitplanung für den Klimaschutz und die Anpassung an den Klimawandel. Raumforschung und Raumordnung 64.3, 161-171, 2006.

FIORELLO, D., HUISMANS, G., LÓPEZ, MARQUES, C., STEENBERGHEN, T., WEGENER, M., ZOGRAFOS, G.: Transport Strategies under the Scarcity of Energy Supply. STEPs Final Report, edited by A. Monzon and A. Nuijten. Den Haag: Buck Consultants International, 2006. http://www. steps-eu.com/reports.htm.

HEILAND, S., GEIGER, B., RITTEL, K., STEINL, C., WIELAND, S.: Der Klimawandel als Herausforderung für die Landschaftsplanung - Probleme, Fragen und Lösungsansätze. Naturschutz und Landschaftsplanung 40.2, 37-41, 2008.

HUBER, F., BROSCH, K., REINBOLD, P., HARTWIG, K.-.H., PEISTRUP, M., SPIEKERMANN, K., WEGENER, M.: Ableitung von Kriterien einer ausreichenden Bedienung im ÖV für unterschiedliche Regionstypen in NRW. Wuppertal: Bergische Universität, 2007. http://www.spiekermann-wegener.de/pro/pdf/MBV_Endbericht_Final.pdf.

IFR – INFORMATIONSKREIS FÜR RAUMPLANUNG: Siedlungsentwicklung und Klimawandel. RaumPlanung 137, 2008.

ILS NRW: Räumliche Szenarien für das östliche Ruhrgebiet. Dortmund: Institut für Landes- und Stadtentwicklung und Bauwesen des Landes Nordrhein-Westfalen, 2005. http://www.ils-forschung.de/down/raum-szenarien.pdf.

INIATIVKREIS RUHR: InnovationCity Ruhr, 2011. http://www.innovationcityruhr.de.

IPCC – INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE: Fourth Assessment Report Climate Change 2007. New York: IPCC, 2007. http://www.ipcc.ch/.

LAUTSO, K., SPIEKERMANN, K., WEGENER, M., SHEPPARD, I., STEADMAN, P., MARTINO, A., DOMINGO, R., GAYDA, S.: PROPOLIS: Planning and Research of Policies for Land Use and Transport for Increasing Urban Sustainability. PROPOLIS Final Report. Helsinki: LT Consultants, 2004. http://www.ltcon.fi/propolis/.

MUNLV – MINISTERIUM FÜR UMWELT- UND NATURSCHUTZ, LANDWIRTSCHAFT UND VERBRAUCHERSCHUTZ DES LANDES NORDRHEIN-WESTFALEN: Handbuch Stadtklima: Maßnahmen und Handlungskonzepte für Städte und Ballungsräume zur Anpassung an den Klimaschutz. Düsseldorf: MUNLV, 2010. http://www.umwelt.nrw.de/umwelt/pdf/handbuch_stadtklima.pdf.

RITTER, E.-H.: Klimawandel - eine Herausforderung an die Raumplanung. Raumforschung und Raumordnung 65.6, 531-538, 2007.

SPIEKERMANN, K., WEGENER, M.: Environmental feedback in urban models. International Journal of Sustainable Transport, Vol. 2, pp. 41-57.

SPIEKERMANN, K., WEGENER, M.: Räumliche Szenarien für das östliche Ruhrgebiet. Schlussbericht. Dortmund: Institut für Landes- und Stadtentwicklungsforschung und Bauwesen des Landes Nordrhein-Westfalen, 2005. http://www.ils-forschung.de/down/raum-szenarien.pdf.

STADT DORTMUND: Handlungsprogramm Klimaschutz 2020 der Stadt Dortmund. Abschlussbericht. Dortmund: Umweltamt der Stadt Dortmund, 2011. http://umweltamt.dortmund.de/upload/ binarydata_do4ud4cms/63/97/20/00/00/00/209763/end-bericht_handlungsprogramm_klimaschutz.pdf.

STB: Schichten einer Region – Kommentiertes Kartenwerk zur baulichen und räumlichen Struktur des Ruhrgebiets. Dortmund: Fachgebiet Städtebau, Stadtgestaltung und Bauleitplanung, Faculty of Spatial Planning, Technical University of Dortmund, 2011.

STERN, N. et al.: Stern Review on the Economics of Climate Change. London: H.M. Treasury, 2006. http://www.hm-treasury.gov.uk/stern_review_report.htm.

UBA – UMWELTBUNDESAMT: Berechnung der Wahrscheinlichkeiten für das Eintreten von Extremereignissen durch Klimaänderungen – Schwerpunkt Deutschland. Dessau: Umweltbundesamt, 2005. http://www.umweltbundesamt.de/uba-info-medien/dateien/2946.htm.

UBA/PIK – UMWELTBUNDESAMT, POTSDAM-INSTITUT FÜR KLIMAFOLGENFORSCHUNG: Klimawandel in Deutschland. Vulnerabilität und Anpassungsstrategien klimasensitiver Systeme. Dessau: Umweltbundesamt, 2005. http://www. umweltbundesamt.de/uba-info-medien/dateien/2947.htm.

WEGENER, M.: The IRPUD Model. Dortmund: Institute of Spatial Planning, University of Dortmund, 2001. http://www.spiekermann-wegener.de/mod/pdf/IRPUD_Model_2001.pdf.