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Editorial

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Abstract. This topical issue collects contributions to the interdisciplinary study of the interacting global systems of public health, energy production, and climate change, in order to provide physicists with an opportunity to explore these fields of application of great societal importance.

As the Intergovernmental Panel on Climate Change (IPCC) summarizes in its 4th assessment report, climate change has already increased the spread of diseases and premature deaths on a global scale through changes in (i) weather patterns (temperature, precipitation, sea-level rise and more frequent extreme events), (ii) air, food, and water quality, and (iii) agriculture, ecosystems, settlements, and industry. These currently small effects on human health include increased heatwave-related deaths and alterations in the seasonal distribution of some allergenic pollen species and the distribution of some infectious disease vectors, and are forecast to increase globally over the century. In particular, projections based on the state of the art scientific models indicate an increase in (iv) malnutrition and related disorders due to crop failures, including those relating to child growth and development, (v) people suffering from extreme weather events such as droughts, floods, fires, heatwaves, and storms, (vi) the operating range of infectious disease vectors, (v) diarrhoeal diseases, (vi) cardio-respiratory problems due to ground-level ozone, and (vii) risk of dengue [1]. The World Health Organisation estimates that the warming and precipitation trends due to anthropogenic climate change of the past 30 years already claim over 150,000 lives annually [2].

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Several of the mechanisms underlying these findings are not yet sufficiently understood to reliably infer robust policy recommendations that would counteract these health implications, not only in developing countries but also in high-income countries which are, e.g., affected by hurricanes and heatwaves of increased frequency and severity. For example, the mixed effects on malaria, with a contraction of geographical range in some places and an expansion elsewhere and changes in the transmission season, involve complex nonlinear spatio-temporal dynamics that are hard to model and analyse with traditional methods.

Climate change affects health also through changes in infrastructure, especially energy supply and use. The United Nations Development Programme reports that (i) local and regional air pollution (e.g., fine particles, ozone, nitrogen, and sulphur emissions) from solid-fuel (e.g., charcoal and fuelwood) cooking, heating, and vehicles may be responsible for more than five percent of the global burden of disease and damages to forests, soils, and lakes, (ii) large-scale hydropower projects in forests and surface mining affect health via changes in the ecosystem, and (iii) most importantly, energy systems account for two-thirds of human-generated greenhouse gas increases driving climate change, thus forming a feedback loop [3].

Even in well-developed industrialized countries and during normal weather conditions, power outages can have severe effects on public health. For example, a major power outage occurred in 2003 in the midwest and northeast United States affecting some 50 million people through loss of refrigeration and multiple municipal infrastructures, in particular municipal environmental systems such as food protection, public water supply, and wastewater treatment, medical services, emergency response, and public health efforts [4]. Independently from their effects on health, power blackouts can impose huge costs on societies [5]. Hence reducing the risk of blackouts is crucially important for both adaptation to and mitigation of climate change because power grid stability is threatened both by volatile wind and solar energy production and by extreme events. E.g., outages onshore can often be corrected quickly so that only a small amount of energy is lost, but with offshore wind energy, the window for carrying out repairs or replacing components is often limited [3]. The larger the share of renewable energy production, and the more frequent and severe weather extremes have to be expected, the more resilient to perturbations one must make the grid. Although, in retrospect, the total costs of a blackout have often exceeded the price tag of additional transmission lines that would likely have prevented this particular blackout in the first place, it is hard to judge in advance which new transmission lines should be built to most effectively improve a power grids stability against blackouts in general.

These complex relationships between health, energy, and extreme events in a changing climate form a prime example of a global complex dynamical system containing several network-like structures including infrastructure networks such as the regional and global power grids, functional networks such as the interaction network of climate dynamics, and socio-economic networks such as the contact network involved in the spreading of diseases. Modern theoretical physics and complex systems science have developed a number of cutting-edge modeling and data analysis methods to infer the individual components' interactions and mechanisms of such systems from data and model their emergent effects.

In particular, complex networks theory [6,7] and the recently developed concept of networks of networks may turn out to be the natural modeling framework for the interaction of health, energy, and climate. Network science has greatly evolved in the past decade and a half, and is currently a leading scientific field in the description of complex systems, which affects every aspect of our daily life. Famous examples include the findings about the Internet and WWW, epidemic spreading, immunization strategies, citation networks, structure of financial markets, social percolation and opinion dynamics, structure of mobile communication networks, and many others. Among the phenomena that have been shown to fall in this conceptual framework are: cascading failures, blackouts, crashes, bubbles, crises, viral attacks and defense against them, introduction of new technologies, infrastructure, understanding, measuring and predicting the emergence and evolution of networks and their stylized features, spreading phenomena and immunization strategies, as well as the stability and fragility of airline networks [8].

In this volume, we bring together theoretical physicists and complex systems scientists with distinguished researchers from the named fields of application to learn about the complex interactions between these global systems and provide physicists with an opportunity to explore fields of application of great societal importance.

In two introductory reviews, Revati Phalkey and Valerie Louis [9] summarize the current body of knowledge on health impacts of climate change, climate-related extreme events, and other natural disasters, stressing the systemic complexity and uncertainties and the needs for integrated research and a pragmatic strengthening of health systems. They also exemplify the nontrivial relationships between climate mitigation, energy use and health using the example of cooking and heating with traditional biofuel still used by almost half the global population.

Focussing on one of the most important vector-borne diseases, Gordon McCord [10] highlights the nonlinear effects of climate change on the malaria burden via roughly estimating the change in the basic malaria reproduction number until the end of the century. To see how extreme events influence epidemics, Jonathan F. Donges and co-workers [11] use the method of coincidence analysis to study the causation of epidemic outbreaks by flood events, thus showing how state-of-the-art statistical methods may help understanding such highly nonlinear process. Addressing another important health-related issue, Tamma Carleton et al. [12] discuss the clear evidence for climate change impacts on violent conflict and social instability and the difficulties in deriving at quantitative projections due to systemic uncertainties such as human adaptation capabilities.

Regarding the causal link from extreme weather events to power grid instability, Yoshito Hirata and Kazuyuki Aihara [13] focus on the question of how sudden rapid changes of renewable energy output due to changes in wind speed may be predicted from time series using machine learning methods in order to be able to take stabilizing countermeasures timely. Studying a particular class of socio-economic responses to climate-related extreme events that has the potential for long-lasting influences on investments and transitions in the energy system, Jesse Anttila-Hughes [14] focusses on stock-market responses and uses an event-based regression method to analyse how announcements of temperature records and ice shelf collapse have influenced investors valuation of energy companies and thus energy stock prices since the 1990s. Roy Allen et al. [15] study the complex interactions between forecasts and agents' reactions to these predictions and show in the example of droughts how this leads to surprising feedbacks between supply and demand.

Several contributions focus on smart solutions for a future energy system that may allow for a higher share of renewables by providing additional means of stabilization and storage. In a simulation study involving hypothetical future grid topologies, Anton Plietzsch and co-workers [16] reveal a trade-off between two forms of stability requiring a different placement of redundant lines. While the more global form of redundancy provided by mesh-like structures improves short-term frequency stability, a more local form of redundancy provided by short detours is required to make the grid more resilient against large-scale outages, which have larger potential consequences for public health. Studying a simple form of decentral smart grid control, Benjamin Schäfer et al. [17] argue that a suitable automatic reaction of consumer demand to grid frequency mediated by a frequency-based pricing scheme may enhance the stability of extended power grid systems, in particular when electricity production is more decentralized. Regarding a promising way in which climate mitigation may be helped by the closer integration of different infrastructure networks, Heidi Heinrichs and Patrick Jochem [18] use a detailed model of the German energy system to show that electric vehicles can be integrated in the electricity system without increasing the system costs but would substantially contribute to decreasing CO_2 emissions. In another regional study, Aleksandar Dedinec and his co-authors [19] use a model of the national energy system of Macedonia to demonstrate that electric vehicles can provide enough storage for a fully renewable energy system and lead to a vast reduction of car traffic pollution. Since many simulation studies rely on a suitable tradeoff between technical detail and simplicity required for tractability and gaining systemic understanding, Sabine Auer and co-authors [20] studied what impact the amount of detail in models of electricity grid dynamics has on typical measures of stability and resilience and found that for many typical questions, voltage dynamics need not be modelled explicitly in addition to frequency dynamics.

We believe that this collection of review and original research shows that the language of theoretical physics and complex systems science is a natural and fruitful framework for this transdisciplinary field, and hope that it will help paving the way for new promising scientific studies and projects in the context of public health, energy production, and extreme weather events in a changing global climate.

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