Preface

Diversity and commonality exist simultaneously in the Danube Region. Along its path from the Black Forest into the Black Sea, the Danube shapes the geography of south-eastern Europe with an outstanding diversity of landscapes. Similarly, throughout the Danube basin a striking cultural diversity has been shaping the socio-political landscape of the region, which today finds its most basic expression in the country borders of thirteen nation states: Germany, Austria, the Slovak Republic, the Czech Republic, Hungary, Slovenia, Croatia, Serbia, Bosnia and Herzegovina, Montenegro, Romania, the Republic of Moldova and Ukraine.

However, commonality sits alongside this diversity; if nothing else because of the common waters that support life throughout the whole Danube basin. On a political level, the European Union Strategy for the Danube Region provides good examples of common challenges and opportunities that the Danube Region nations face for ensuring sustainable socio-economic development [COM(2010)715], of which energy is one of the issues highlighted. Energy production in the Danube Region is predominantly based on fossil energy sources, which contribute to climate change, endanger the ecosystem and lower the quality of life. The large-scale use of nuclear energy passes the problem of nuclear waste to future generations and exports the heavy and dangerous externalities of uranium mining to countries with low environmental awareness, such as Russia, Ukraine and Kazakhstan. Moreover, most of the national energy systems in the region are highly dependent on external energy resources which, in turn, underlines the region's vulnerability to periodic crises and geopolitical shifts. Although the share of renewable energy sources (RES) in final energy consumption has grown steadily in the last decade, the national energy strategies in the Danube Region are still mainly based on fossil and nuclear sources.

Against this background, the Hungarian Academy of Sciences and the Wuppertal Institute for Climate, Environment and Energy initiated the project "Perspectives of Renewable Energy in the Danube Region", which was financially supported by the Deutsche Bundesstiftung Umwelt DBU (German Federal Environmental Foundation). The overarching goal was to provide a platform for international and multidisciplinary discussions on the challenges and opportunities for renewable energy sources in the Danube Region as a central option in the transition towards a post-carbon and post-nuclear era. The project comprised two main elements: a preparatory workshop and an international conference. The workshop was organised in

order to establish the main constitutive aspects of the problem and took place at the Institute for Regional Studies at the Hungarian Academy of Sciences in Pécs, Hungary on 26 September 2014. It brought together 35 researchers with diverse perspectives from seven Danube Region countries working in the field of energy. Based on the outcome of the workshop, a call was launched inviting scientific contributions offering valuable insights on the challenges and opportunities for renewable energy sources as an option for energy transition in the Danube Region. The contributions (in the form of abstracts) were evaluated and the researchers who submitted the most interesting contributions were given the opportunity to present and discuss their studies at the international conference, which took place in Pécs on 26 and 27 March 2015.

This book is a tangible product of the discussion process initiated by the project, collating the contributions made by experts from different backgrounds who shared their work at the conference. The book can be understood in terms of an analytical exercise, gradually breaking down the status and dynamics of renewable energy in the Danube Region into more specific issues. This analytical aim is reflected in the structure of the book, which follows the structure of the conference.

The book opens with an introductory paper from Professor Márta Somogyvári, who proposes examining historical energy transitions in order to establish categorisations that can help us to grasp the current dynamics in the energy systems of the Danube Region. Her analysis illustrates, on the one hand, the disparities among the energy transition processes in the region: appreciable towards the 'centre' (e.g. Germany); almost non-existent towards the 'periphery' (e.g. Serbia). On the other hand, it suggests that "the main inhibitor(s)" today might be found in the political economy of the process rather than in the mere technical viability of the transformation. Professor Somogyvári's contribution immediately provides strong indications of the need to approach the topic from a system perspective, i.e. to consider the broader (existing) socio technical energy systems, where renewable energy dominance is expected to emerge. Such energy systems comprise different (non-technical) domains, such as politics, economy and society in general, but also include physical (e.g. power grid and gas networks) and non-physical (e.g. cognitive paradigms and institutional arrangements) infrastructures, which ensure the proper function and maintenance of the systems.

The first part of the book presents contributions which aim to understand the current and future role of renewable energies as components of broader energy systems on different geographical scales, or by considering their interactions with the social or economic domains. Papers relating to those subjects are divided into three sections: "Systemic Components and Constrains", "Social Domain" and "Economic Domain". In contrast, the second part of the book is dedicated to exploring the particularities of renewable energy resources in the Danube Region and contains five

sections: Hydro Energy, Wind, Geothermal, Solar and Biomass Resources. The majority of the studies in those five sections aim to provide responses to the question of how specific renewable energy potentials in the Danube Region can be harnessed in an effective and sustainable way.

The first section ("Systemic Components and Constrains") is opened by Professor Tamás Katona's critical analysis of the existing (physical) infrastructure in Europe, particularly the power generation and transmission infrastructure. His analysis suggests that the current infrastructure is "hindering the development of the integration of renewable energy sources". He also points at the huge investment in power generation and transmission required in Europe during the next decade, which does not necessarily emerge from the need for energy transition but rather from the aging power infrastructure in most European countries. The study by Mathis Buddeke, Christine Krueger, Arjuna Nebel and Frank Merten complements this European perspective by investigating the capability of power storage, demand side management and international grid exchange to balance the residual power demand in Europe in a future scenario with a high penetration of renewable energies. Their results underline the need for the integration of European power systems, as well as for the expansion of the grid, in order to effectively manage high shares of renewable power. Jenö Zsolt Farkas, Edit Hoyk and András Donát Kovács discuss the options and constrains of middle-sized Hungarian cities as places for driving the transition towards low carbon energy systems. They find that policies at national level have a strong influence on local considerations and, although renewable energies are often components of cities' climate protection strategies, Hungarian national energy policy is mainly focused on the further development of nuclear power. Against this background, local actors often put greater emphasis on energy efficiency measures, which appear to be more practical at local level from a political and financial perspective. Closing this section, Danijel Topic, Anton Spajic, Stanislav Vezmar and Damir Sljivac provide an overview of the state and potentials of renewable energy at a sub-regional level. Their review covers the Croatian Danube Region, which includes the Vukovar-Sriem and Osijek-Baranya counties.

The "Social Domain" section gathers approaches related to the topic from the social sciences (with the exception of economics) and fully recognises that methods, concepts and topics from the social sciences "remain underutilized, and perhaps underappreciated, in contemporary energy studies research" (Sovacool 2014). The section opens with a contribution from László Berényi, who puts forward and discusses factors that can be used to assess the social aspects related to the increasing penetration of renewable energies. Two papers follow this contribution, both of which use the theory of environmental modernisation as their conceptual framework. Based on his analysis, Dragos Constantin Sanda suggests that the increasing penetration of renewable energies in Europe – and particularly in Romania – are

already positive signs of the viability of environmental modernisation. Alexandra Luana Sanda comes to a similar conclusion in her paper, although her analysis focuses on the dynamics of the "green" labour market, which is linked to the growing renewable energy sector.

Contributions in the "Economic Domain" section offer insights into the political economy of renewable energies in the Danube Region. The section begins with a paper from Nikolett Deutsch and Éva Pintér, who propose a framework for analysing the market competitiveness of renewable energies. They organise the broad set of influential factors into four categories of "barriers": political and legal, technological, social and market. By applying their framework to renewable energy promotion policies in place in the Danube countries, they conclude that "there is no trade-off between risk and return because of the constantly changing conditions". We would add to their conclusions that their findings suggest the need for deeper analysis of the political domain and, particularly, the power structures intertwined with the energy sector in most of the Danube countries. To some extent, the paper by Sorin Cebotari complements the introductory contribution from Nikolett and Pintér, as it provides a critical analysis of the Romanian power sector. Cebotari not only presents a clear overview of the striking development of the Romanian renewable energy sector in the last decade, but his analysis also highlights the most critical issues which will determine the further development of the sector: "underdeveloped grid capacity and interconnections and the unstable/uncertain institutional arrangements". Interestingly, Cebotari's findings underline (from a country level perspective) the role that grid and market integration beyond national borders might have in a future with deeper penetration of renewables. In their contribution, Éva Szabina Somossy and Tamás Tóth consider innovative integration options, i.e "joint renewable energy support schemes". They discuss analytical models that describe the function of support schemes reaching beyond national boundaries and the expected improvements in the aggregated cost-benefit ratio. They apply those models to two potential groupings: a Central-East-Europe group including Austria, the Czech Republic, Hungary and Slovakia, and the Visegrád countries, which would combine the "Czech-Slovak-Hungarian (and perhaps Polish) market(s)". Their analysis points to "the sharing of indirect benefits (local job creation, spillover effects, local value added, etc.)" as the most difficult issue for a real application of the schemes. This, in turn, underlines the assertion that developing strong political cooperation in energy topics is a prerequisite for measures that aim to advance the integration of energy infrastructures and markets.

The part of the book dedicated to exploring the particularities of renewable energy resources in the Danube Region opens with the Istvan Szeredi's contribution on hydro energy. He initially reviews the status and potential of hydroelectric power in the Danube Region and then focuses specifically on the Hungarian case. Against a

background of increasing power imports, rising demand and decreasing off-peak prices in the wholesale power market, among other factors, Szeredi's analysis provides strong arguments for allocating a significant role to hydroelectric power in the reconfiguration of the Hungarian power system, particularly for its "capability to stabilise fluctuations between demand and supply".

The section dedicated to "Wind Resources" begins with a brief overview of the penetration of wind power in the Danube countries (excluding Germany) by Ildikó Dobi Wantuch. His analysis shows that the wind power sector in most of the Danube countries is at a rather early stage, or is even, in some cases, practically non-existent – despite the fact that significant potential is recognised throughout the region. A common barrier is regulatory uncertainty for wind power investment. One prominent issue is the definition of areas available for wind power developments. Two papers in this section address this issue by applying geographical information systems and exploring the actual potential for wind power in diverse economic, technical and environmental circumstances. Nándor Csikós and Péter Szilassi propose a methodology to "locate those areas that are perfectly or moderately suitable for building wind [power capacities]". They apply their methodology to the county of Csongrád in southern Hungary. In this way, they demonstrate how the methodology is suitable for exploring how both the geographic distribution and the aggregated wind power potential are influenced when considering different definitions of buffer zones. Béla Munkácsy, Ádám Harmat and Dániel Meleg apply similar methodology in order to assess Hungary's technical wind power potential. They estimate that 19.6% of the Hungarian territory is legally available for wind power development. Moreover, Munkácsy and his colleagues propose to complement the assessment by applying a comparative analysis between Hungary and Eastern Germany in order to estimate what they call the "socio-economic" potential. Accordingly, they estimate that reaching a total wind installed capacity of 10,286 MW in Hungary by 2050 is viable. Under that scenario, only 1.1% of Hungarian territory would be used for wind power developments. Károly Tar, István Lázár and Renáta Gyarmati provide the last contribution in this section. They address the predictability issue of wind power, which is critical for the daily management of wind power capacity and ultimately for the financial performance of wind projects. Tar and his colleagues propose a statistical method to "determine the probability of increase or decrease of daily average wind speed and wind power to the next day". Their results indicate that it would be worthwhile to further develop and test the method for its application under actual operating conditions.

Annamária Nádor and Szilárd Árvay open the section dedicated to "Geothermal Resources". Based on up-to-date information they provide an overview of the potential and actual use of geothermal resources in the Danube Region. Their study clearly exemplifies the significant potential available in almost all Danube Region countries,

but also illustrates the rather marginal role that geothermal energy currently plays. Nádor and Árvay also identify challenges common to most of the Danube Region countries, such as the low rate of reinjection and low thermal and utilisation efficiency (which often lead to overexploitation in the case of existing plants), but also the fragmented regulatory system, the lack of financial incentives and the need for more accurate data on geothermal resources in order to make informed decisions on the development of geothermal potentials. In the second half of their contribution, Klára Szita Tóth and Anna Vizkeleti complement this overview by discussing actual usages of geothermal resources in Hungary. Tóth and Vizkeleti describe some exemplary cases of geothermal energy applications for district heating in Hungary and provide some data on a pilot project for an enhanced geothermal power plant expected to be established in the coming years in Hungary's Southern Great Plain. In their paper, Erika Bódi, Tamás Buday, Réka Lilla Kovács, Richard William McIntosh and Miklós Kozák address the need, already mentioned, for more accurate data on interesting reservoirs. Bódi and her colleagues develop a 3D geological model for a location in Hajdúság (Eastern Hungary), which is part of the Pannonian Basin. This is a location where 24 thermal wells are used for balneological or geothermal energy extraction purposes. Their results underline the need for accurate models of the distribution of geothermal reservoirs as a prerequisite for the more efficient and more sustainable management of resources. Moreover, their observations reinforce the concern, which has already been mentioned, about the overexploitation of reservoirs in existing geothermal facilities. Examples of the utilisation of geothermal resources from the same Pannonia basin, but in this case in the Romanian Western Plain, are given by Mircea Gordan, Cristian Vancea, Cornelia Gordan, Maria Bittenbinder and Monica Costea in their contribution. They describe the main geological features and the utilisation of two fields close to Oradea, Romania. Particularly interesting is the cascade approach applied by the system installed at the University of Oradea, which contains two utilisation loops for the geothermal water. Gordan and his colleagues also report on a prototype for a thermoelectric generator that uses geothermal water and provides 30 to 50 W during operation. This micro-generation concept represents an interesting option for complementing the cascade utilisation already in place at the university. In contrast to the previous contributions, Tamás Buday, István Lázár, Gergely Csákberényi-Nagy, Erika Bódi and Tamás Tóth address the energy potentials of shallow systems. Based on meteorological data from the Renewable Energy Park in Debrecen (Eastern Hungary), which include soil temperatures at 9 different depths, Buday and his colleagues investigate the effect of solar radiation and other climatic variables on underground temperature. While the effect of solar radiation is significant in the shallow regions, the recovery effect is hardly appreciable at depths greater than one metre, which is particularly critical at the end of the cold season.

Based on their results, Buday and his colleagues suggest some practical recommendations for siting and design.

Professor Damir Šljivac opens the "Solar Resources" section by discussing the overall distribution of solar irradiation in the Danube Region. Although – in general terms – the "Danube Region lies in the area favourable for solar energy generation", Professor Šljivac emphasises that the actual usable potential depends on parameters such as "the type of technology, configuration of the energy system and the efficiency in converting the solar irradiation to electricity and/or heat". Exploring the effect of different technology types, system configurations and national regulations on the economic performance of investments in solar PV is the main aim of the contribution from Denis Pelin, Sándor Zsolt Kovács, Andrea Suvák, Damir Šljivac and Danijel Topić. They undertake a cost-benefit analysis of investment scenarios resulting from the combination of five different PV technologies, two system configurations and four countries. Not only the final figures on cost-benefit ratios, but also many of the intermediary results from their study, provide valuable data for further research and development of practical applications of PV in the countries studied: Croatia, Hungary, Serbia and Slovenia. In contrast to the techno-economic approach of Pelin and his colleagues, Lea Végh's study addresses one of the major concerns relating to large scale photovoltaic developments, i.e. the need for large areas and the potential impact on landscape fragmentation. She proposes a methodology based on geographical data in order to identify degraded areas in Hungary, where large PV developments are technically viable but would not necessarily result in negative environmental impacts. In order to refine her assessment, she proposes a definition of 'degraded sites' that considers degradation through landfill, mining and agricultural land prone to frequent inundations. The results, and particularly the methodology proposed, present promising options for further research and development in this particular field in both Hungary and the Danube Region as a whole. The section on solar resources closes with a case study on the application of solar water heating at a secondary school in Croatia. Marinko Stojkov, Krunoslav Hornung, Ante Čikić, Dražan Kozak, Damir Šljivac and Danijel Topić explore the potential reduction in natural gas consumption that can be achieved by integrating a solar water heating system with the existing central heating system. They conclude that the suggested solar thermal system could replace 23% of the school's annual gas consumption.

The section relating to "Biomass Resources" contains contributions analysing the suitability of two plants (sugar beet and reed) as primary energy sources. Laszlo Potyondi elaborates on several arguments around the suitability of sugar beet as an energy crop and discusses aspects such as the high yield of ethanol per hectare, the suitability of sub-products as animal feed and the possibility of using all or part of the plant as substrate for biogas production. Ultimately, Potyondi's analysis opens the field for further and deeper research on the role that sugar beet could play in low-

carbon energy systems, i.e. the technical, economic, social and environmental aspects linked to scenarios with increasing production of sugar beet as an energy crop. Jürgen Krail, Hannes Kitzler, Georg Beckmann, Helmut Plank, Christoph Pfeifer and Doris Rixrath present a comprehensive investigation on technically viable possibilities for configuring a value-chain of reed pellets. They assert that reed pellets are suitable for domestic heating or larger district heating systems, but also note that it is preferable to use them in combination with conventional fuels. Doris Rixrath, Jürgen Krail and Arne Ragossnig complement the analysis of reed as an energy resource by analysing the market competitiveness of different value-chain configurations. To that end, they estimate the total production costs of reed-based fuels and compare them with conventional (bio)fuels. According to their estimations, the production of reed pellets can be economically competitive under current market conditions. Moreover, they note that considerable cost reductions are possible by improving the harvesting process.

If it were possible to sum up the diverse aspects and findings shared by the authors of the contributions in this book and the conference participants, the main emerging message would be that there is significant potential in the diverse conditions of the Danube Region countries and considerable knowledge about sustainable energy transitions. Many contributors agree that the main challenges are neither technical nor economic but are, in fact, institutional, due to the current status of different national energy systems which have little connection to each other. In addition, there is often limited awareness of the opportunities that the transition to sustainable energy can offer, such as improving the security and stability of national energy systems, labour markets and regional economies. Creating more opportunities to share and discuss ideas, experience and knowledge relating to common challenges will certainly help to clarify the issues and to build the knowledge base to facilitate the transition to a more sustainable energy system in the Danube Region.

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