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Geothermal energy and society: experience around the world

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ABSTRACT

This presentation outlines the main results collected in the second edition of the book “Geothermal Energy and Society” by Springer Pub. (Manzella, Allansdottir, and Pellizzone (Eds.)). The book explores the diverse aspects of the relationship between the technological harnessing and development of geothermal resources and the societies and local communities in which these developments occur. The responsible use of geothermal energy can help mitigate the effects of climate change and contribute to the development of a renewable and sustainable energy mix in the transition toward a resilient and net-zero carbon society. As with all other developments in the energy sector, a sustained societal dialogue is essential as society plays an active role in either accelerating or preventing the development of new energy technologies. The new volume introduces a theoretical framework for a social scientific approach to the field and represents a new and enriched collection of empirical case studies on geothermal energy and society from across the globe, providing some recommendations for future research and policies in the field.

INTRODUCTION

Geothermal energy can significantly contribute to the shift to clean, reliable, and affordable renewable power. Equally crucial is ensuring this shift promotes a "just transition," providing adequate support to regions in transition and preventing citizens from bearing excessive energy costs. Alongside technical hurdles, societal challenges also arise as technological solutions can be broadly adopted or rejected by society and local communities. In order to be successful, innovations need to be tailored, supported, and ultimately integrated into the market. For over a decade, across different regions worldwide, there has been a growing effort to engage the public, understand their perceptions of geothermal technologies, and raise awareness about geothermal externalities and benefits. The first edition of 'Geothermal Energy and Society” (Manzella et al., 2019) marked the initial effort to compile how various societies have considered social factors in developing geothermal technologies. It presented the subject from technological, regulatory, and socio-economic viewpoints and featured case studies from different countries worldwide.

Since the publication of the first book, the renewable energy sector, including geothermal technologies, has grown significantly in strategic and political importance. Additionally, energy policy has been heavily influenced by urgent issues like climate change and rising geopolitical tensions. The climate crisis is increasingly prominent in global public discussions, with policy measures to address climate change and develop efficient, secure, and resilient energy systems taking center stage on the political agenda. Furthermore, political events such as tensions with Russia in Europe, along with the need to reduce reliance on single energy sources, have substantially altered the energy markets, emphasizing energy security concerns. However, green policies have sparked controversy in various policymaking contexts, often challenging societal consensus on future energy strategies. Consequently, the question of how different societies worldwide address the issues related to potential developments in geothermal energy has become increasingly important.

Given the successful reception of the first edition, the publisher invited us to prepare a second edition, which was published in the summer of 2025 (Manzella et al., 2025). The new edition is fully updated and retains all the case studies from the previous book, with most of the original authors contributing. Only two chapters remain in their original form. The global view of how geothermal energy interacts with society has been enhanced by adding new, engaging country case studies that expand beyond Europe and the Western world.

At first glance, this volume can be seen as fostering connections between various disciplines (i.e., earth sciences, engineering, and social sciences), and the interdisciplinary nature of this work is clear from the diverse expertise of the contributing authors. However, the goal of this publication goes beyond simply linking different fields of study and nations around the world. By identifying those who supported social scientific research on

geothermal energy and society within each country and adopting a systemic approach, we aimed to explore the interaction between energy and society as an emerging disciplinary area in its own right. This process seeks to develop new tools for participatory governance of geothermal energy and energy innovation.

This paper synthesizes the book's content and suggests future steps. It compares public engagement mechanisms globally, analyzing their impact on energy innovation policymaking. It also explores factors affecting geothermal development's attractiveness and the public's understanding of geothermal energy.

1 BOOK CONTENT AND METHODS

The book has two main sections, along with an introduction and conclusion. The first section presents key topics, helping readers understand the overall content regardless of their background. After a brief overview of geothermal terminology and harnessing technology, the discussion moves to global incentives and support initiatives for geothermal development, focusing on policies and regulations in Europe and how this regulatory framework has changed over time. The discussion then shifts to sustainable geothermal development and innovation as paths to a clean and fair future. Lastly, the section introduces conceptual and methodological frameworks that can guide research and activities related to geothermal energy and society. The second section offers country profiles with case studies from fifteen countries worldwide (Fig. 1). Many of these countries either produce notable amounts of geothermal energy or have significant social engagement connected to geothermal development. The case studies follow a common framework to make it easy to compare similarities and unique features of each country.

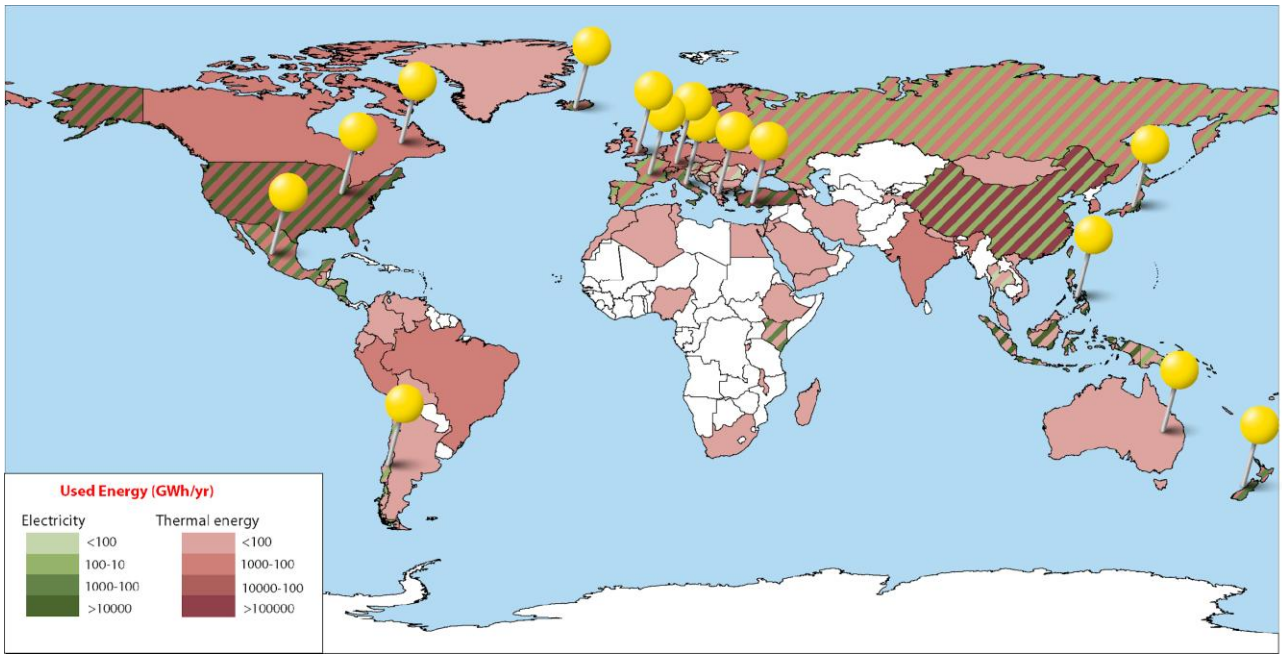

Figure 1. Global overview of geothermal production (countries producing heating and cooling in red, countries producing electricity in green. Stripes indicate production of both heating and cooling and electricity). Yellow pins highlight countries described in the 15 case studies. Data Source: Gutiérrez-Negrín (2023), Manzella (2023). Based on an image by Laura Criscuolo, Elisa Cannone, Martina Rosa Galione, Adele Manzella (CNR-IGG) licensed under CC BY-NC 4.0 (2024)

2 COMPARISON, FINDINGS AND DISCUSSION

2.1 The motivations behind geothermal development

Understanding what drives geothermal development helps us appreciate its importance and potential benefits. Exploring these motivations can inspire greater interest and support for sustainable energy solutions.

The history of geothermal development predates human existence. Humankind and its ancestors have used geothermal waters since at least the Paleolithic era, mainly for bathing, washing, and preparing food. Various drivers acted to develop further. At the start of the 20th century, advances in technology for generating electricity from geothermal fluids emerged as a means to lower the costs of industrial processes. The severe economic crisis of the 1930s was addressed by developing affordable geothermal heating systems to provide comfort for

local communities and towns. These initiatives received broad societal support. Another major wave of geothermal development took place during the oil crisis of the 1970s, as countries searched for alternatives to fossil fuels, highlighted in the book's case studies of France, Iceland, the Philippines, Greece, and Chile. The 21st century has seen a growing focus on renewable energy technologies, including geothermal, as a way to address climate commitments and decarbonize the energy sector, although proposed solutions remain widely debated (Jasanoff, 2018). The commitment is increasing and shaped by politics and energy instability. For example, the Fukushima disaster and related concerns about nuclear power increased interest in renewable and sustainable energy sources, and the recent war in Ukraine highlighted the need for energy security. During the December 2023 COP28 in Dubai, 118 nations agreed to triple global renewable energy capacity by 2030 to help limit the temperature rise to 1.5 °C, and the IEA Sustainable Development Scenario forecasts a tripling of geothermal production by 2030, with a significant contribution from heating and cooling. Currently, there is no shortage of drivers, and technological advancements like EGS, AGS, drilling technologies, as well as AI and ML exploration methods, are essential for achieving the target and opening up new prospects for development.

2.2 Energy products and public perception of the technologies behind them

The difference between producing heat and generating electricity is not just a matter of technology. Firstly, using heat directly has a much longer history than generating electrical power. This straightforward fact is evident in countries such as Chile, France, Iceland, Italy, and Japan, as shown in the book. The geographical scope also varies, with 88 countries reporting heating and cooling applications and only 31 countries involved in electricity generation. It is clear from reading the book that local communities usually favor heating and cooling applications, despite some unavoidable disputes over certain developments. This is not always the case with power plants and electricity generation. There could be various reasons behind this observation. This acceptance often stems from the direct benefits to users and the growing familiarity of local communities with the technologies used, especially for small to medium-sized applications such as space heating and cooling by geothermal heat pumps or agrifood processes. Although the energy source remains the same, technologies extracting energy from deep depths might be seen as riskier because of the physical (temperature, pressure) and chemical (pollutant and gas content) characteristics of the geothermal fluids. Moreover, while geothermal resources have long been important to communities with access to them, deep geothermal applications for heating, cooling, and electricity are still generally unfamiliar to many societies and the public, as shown in the country profiles. In several countries, there is considerable confusion about geothermal energy compared to more well-known renewable sources such as wind and solar.

The sources of concern and uncertainty can vary. Societies often lack sufficient information about geothermal technologies, including their risks and advantages. This issue is particularly noticeable in Canada, especially Quebec, as well as in Italy and Mexico. Substantial efforts are required to address these gaps and advance the field. Concerns also arise from previous negative experiences that become prominent in discussions about new developments. The French chapter mentions two examples: the stalled pilot projects for deep geothermal electricity in Guadeloupe and Réunion, as well as the difficulties encountered in Alsace and the Rhine Basin in mainland France. Additionally, the historical controversy over geothermal power plants on the Greek Island of Milos in the 1970s continues to impact discussions about geothermal energy in Greece. Nonetheless, negative results do not always reduce public enthusiasm for developing deep geothermal resources, as demonstrated by the St. Gallen case in Switzerland. Iceland offers a further perspective, focusing less on the power generation technology itself and more on the intended use of the electricity—specifically, how it will be utilized and who will benefit. Additionally, problems linked to other energy technologies, like shale gas fracking, influence public perceptions and understanding of geothermal energy development, as observed in country case studies such as the UK and Mexico.

The perception also varies significantly between countries with abundant internal electricity supply—such as Iceland, New Zealand, and the Philippines—and those like Italy, where geothermal energy only supplies a small part of their large energy needs. In Turkey, a sharp rise in electricity demand has strengthened the push to use clean renewable sources like geothermal energy, highlighting the country's commitment to a low-carbon, sustainable future. The link between energy demand levels and the drive for development and innovation in this sector warrants further investigation.

2.3 Ownership and management of geothermal resources

The laws and regulations related to the ownership, usage, trade, and management of geothermal resources vary considerably among the countries covered in the book. Although a detailed analysis of this topic goes beyond our scope, it is worth briefly noting how legislation influences geothermal development.

Countries like Switzerland and Greece lack comprehensive regulations for the harnessing of geothermal resources. The processes for authorisation and licensing are managed by different administrative levels worldwide. For example, in France, geothermal resources are governed by national mining laws, which can cause conflicts between local and national authorities, affecting local democracy. In Japan, geothermal resources are locally regulated under the Hot Spring Law due to historical reasons, creating tensions between onsen (spa) operators and other geothermal projects. New Zealand has a distinctive framework that promotes sustainable management, reflecting the strong cultural and historical ties of the Maori people to these resources. This link between culture, history, and nature is also highlighted in chapters about Chile, Japan, Mexico, New Zealand, the Philippines, and the USA. One might question whether this explains why New Zealand and the Philippines have put in place some of the most comprehensive regulatory frameworks for public engagement and consultation in geothermal development.

Despite having just fifteen case studies, examining how these regulatory frameworks relate to debates on developments and innovation in the geothermal sector presents an intriguing area of analysis for the future.

2.4 Geothermal energy and societal engagement

There is a remarkable variety of activities, insights, and social scientific studies carried out within each nation covered in the book to address many relevant research questions. Let us explore some of these, with the hope that this can inspire engaging international comparative research projects in the future.

An interesting research question is who initiates and funds social scientific research on geothermal energy. In some countries like Australia, public authorities invest in this research while evaluating the potential for development and innovation in the geothermal sector. These studies typically use methods such as surveys, interviews, and focus groups, with much of the research already published globally. Conversely, in countries like Turkey, this kind of research lacks governmental support and is driven by the interests of individual researchers. In Iceland, community movements have recently voiced concerns about expanding geothermal use for electricity, but social scientific analysis of public opinion and citizen involvement remains limited. In Italy, France, and Québec, Canada, country profiles show multi-method approaches in publicly funded case studies as part of scientific and engineering investigations into geothermal resources. Most of these studies have also been published internationally.

Switzerland's profile highlights a strong and institutionalised tradition of direct democracy at all levels, including various activities, public consultations, and social scientific research on geothermal energy. This raises an interesting question: how do different countries develop forms of citizen participation and public engagement, and what influence do they have on national and global debates about geothermal innovation? Although there isn't enough space to explore these and other questions in detail, the book provides valuable insights for further investigation.

2.5 The determinants of public views on geothermal energy

Reading through the book reveals that the potential of utilizing geothermal resources for energy is generally not well known or understood by the public worldwide. Since geothermal energy often appears uncertain to many, factors beyond mere risks and benefits tend to dominate the discussion. Apart from some shared issues in the case studies, such as a preference for heating and cooling applications over electricity generation, the variety of contexts highlights additional influences—spiritual, historical, economic, and political—that impact the attractiveness of geothermal development.

Geothermal resources are often located in areas that are considered sacred or spiritually important to local and Indigenous communities. While these considerations may be less relevant in some case studies from continental Europe and the UK, they are essential in research from the Americas, Asia, and Oceania. Indigenous peoples often have strong ties to nature, reflecting their core beliefs about humanity's connection with the environment. This relationship calls for the adoption of participatory approaches and policies for land management and resource use.

Historical and territorial factors may significantly shape perceptions of geothermal energy. Geopolitical issues in areas like Ukraine and the Middle East, combined with the climate crisis, have shifted focus toward energy independence and diversification, becoming key topics in politics and public discourse. This increased interest often highlights geothermal energy as a solution. Similarly, geothermal energy is a core part of regional identities in places like Iceland, New Zealand, and on a more regional level, such as in Larderello, Italy, where the community's development is closely tied to its geothermal industry.

As previously mentioned, negative past experiences with geothermal energy tend to linger in public memory, influencing debates about new projects. The book examines this issue in Greece and Switzerland. The incidents in these countries have caused lasting public worry and have influenced perceptions of geothermal risks for many years, possibly decades. Furthermore, advancements in technology fields unrelated to geothermal energy can impact its perception, either by hindering or encouraging it. The chapters on the UK and Mexico demonstrate that debates over hydraulic fracturing for shale gas in the UK or negative experiences from Mexico's mining sector can have a spillover effect, influencing the public's view of geothermal energy.

Procedural and distributive justice issues are key in shaping how geothermal energy and its uses are perceived, as shown in numerous case studies in the book. The overarching themes of justice and democratic governance are deeply connected to local cultures and the diverse national contexts discussed here, leading to different understandings of similar concepts. Several chapters explore the distribution of benefits and costs, considered as an essential basis for fairness in geothermal projects, whether for electricity generation or heating and cooling solutions. Encouraging citizens to join energy communities, a new form of localised energy governance, is suggested as a method to promote engagement and active participation in the energy transition. However, in some countries, such as the UK, regulations create hurdles by favoring large-scale, operator-driven plants over smaller-scale connections. The Icelandic case study highlights the significant collective benefits of geothermal energy use. Because geothermal energy is abundant relative to the country's energy demand, the discussion shifts from how to generate enough to meet national needs to whether to produce it at all and for which purposes. The concerns now focus not on geothermal technologies but on the potential environmental impacts of the energy's users, such as heavy industry.

3 CONCLUSIONS

The book does not aim to provide a complete and unified collection of studies, but it currently remains the only comparative overview of geothermal engagement in the sector. Its main goal is to inspire future research and reflections on the interaction between geothermal energy and society. Utilizing the book's material will require further study. We believe that the book represents just the initial step in a broader research effort that includes technical and societal considerations to ensure the responsible and sustainable use of geothermal energy.

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