



# Editorial: Energy, Resources and the Environment – Interdisciplinary answers to approach the sustainable energy and resources conundrum

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**Abstract.** Every year, the European Geosciences Union (EGU) brings together experts from all over the world at its General Assembly, covering all disciplines of the Earth, planetary and space sciences. The EGU Division on Energy, Resources and the Environment (ERE) is concerned with one of the humankind's most challenging goals – providing affordable, reliable and sustainable energy and other georesources. A collection of contributions from the ERE Division at the EGU General Assembly 2018 is assembled within the present special issue in *Advances in Geosciences*.

## 1 Introduction

The EGU General Assembly 2018 (“EGU 2018”) was held from 8 to 13 April in Vienna, Austria. 15 075 scientists from 106 countries participated in the conference, with 4776 oral, 11 128 poster, and 1419 interactive presentations in 666 unique scientific sessions as well as joint 68 short courses and 294 side events.

The EGU scientific activities are organized within 22 divisions. The ERE Division is one of these and hosted 18 sessions with 364 presentations and co-organized another 13 sessions with other divisions. This volume of *Advances in Geosciences* contains scientific papers covering a large range of topics in the fields of energy, resources and the environment, that were presented in the ERE sessions at the EGU

2018 and continues a series of special issues from the past years (Kühn et al., 2013, 2015, 2016; Juhlin et al., 2014; Martens et al., 2017).

## 2 The ERE scientific program in 2018

The United Nations' 17 Sustainable Development Goals (SDGs) from 2015 set the world on a path towards more sustainable development through the adoption of the 2030 Agenda for Sustainable Development (UN, 2015). The SDGs set out quantitative objectives across the social, economic, and environmental dimensions of sustainable development, all to be achieved by 2030. About half of the SDGs are directly environmental in focus or address the sustainability of natural resources. SDG 7, for instance, is to ensure access to affordable, reliable, sustainable and modern energy for all. SDG 12 (Responsible consumption and production) is also relevant for ERE and it was demonstrated that this goal is top ranked in terms of links and dependencies with other goals (Le Blanc, 2015), putting issues discussed within our division at centre stage in context of SDG mainstreaming.

One goal of the ERE division is to address urgent energy and environmental opportunities and threats and to be a leading forum for discussions. Hence, the scientific program of the ERE division included the following seven subprograms in 2018:

- Integrated studies,
- Impact of energy and resource exploitation on the environment,
- Non-carbon based energy,
- Carbon based energy,
- Geo-storage for a sustainable future,
- Thermal-hydro-mechanical and chemical processes related to geoenery,
- Geo-materials from natural resources.

## 2.1 Integrated studies

With the subprogram “Integrated studies”, ERE was in the lead for three scientific sessions. The first one on “Energy, Resources & the Environment” provided an overview on integrated studies, which are indispensable to tackle the challenges of the future.

The session “Energy and environmental system interactions – Policy and modelling” considered that the transition to a low-carbon energy regime to mitigate greenhouse gas emissions and combat climate change, together with the need to meet future demands and security of energy supply, presents a major challenge for many governments. Meeting these challenges would require significant changes to the whole energy system, including the deployment of new technologies, expansion of power generation capacity and significant levels of demand-side management. This session discussed novel approaches for analysing energy and Earth/environmental systems interactions and their implications for policy and society.

The session “Responsible mineral and energy resource development” addressed the fact that mineral and energy resources are an integral part of any foreseeable economy and society. Responsible resource development, use and exploitation have the opportunity and potential to positively contribute to all SGDs of the United Nations as explained above. Such resource development requires state-of-the-art knowledge and intelligent management systems. Solutions for this grand challenge can only be achieved through a multi-disciplinary approach and by combining comprehensive knowledge in the geosciences with that of economic, legal and engineering disciplines.

## 2.2 Impact of energy and resource exploitation on the environment

The session “Environmental impacts of hydraulic fracturing: Measurements, monitoring, mitigation and management” brought together scientists from various disciplines involved in research on the geological, geochemical, geophysical, geomechanical and (micro-)biological processes that control the environmental impact that shale exploitation will or may

have on the subsurface, surface and atmosphere. The accelerated growth of oil and gas production from shale formations is accompanied by growing public concern on the environmental impacts. Main concerns are related to hydraulic fracturing which is required for oil and gas production from unconventional reservoirs, like e.g. shale gas.

Within the session “Petroleum exploration and production and their impact on the environment” new advances in oil and gas exploration and production technologies as well as their associated environmental risks and economic benefits were presented.

## 2.3 Non-carbon based energy

Wind and solar power are the predominant new sources of electrical power in recent years. Solar power reached a milestone of providing 50 % of demand in Germany during one hour in 2012, and wind power during one hour in 2015 exceeded 140 % of demand in Denmark. By their very nature, wind and solar power, as well as hydro, tidal, wave and other renewable forms of generation are dependent on weather and climate. Presentations in the session “Energy meteorology and spatial modelling of renewable energies” showed that modelling and measurement for resource assessment, site selection, long- and short term variability analysis and operational forecasting ranging from minutes to decades are of utmost importance.

Marine renewable energy includes offshore wind, wave, tidal range (lagoons and barrages), and tidal-stream energy. Understanding the environment these marine renewable energy solutions are likely to operate in is essential when designing efficient and resilient technologies; furthermore, accurately charactering the resource, and likely impacts, is essential for the development of the marine renewable energy industry. The session “Marine renewable energy; resource characterisation, interactions and impacts” shared information on new research techniques and methods to better understand the resource, and the interactions with energy extraction and the environment.

The session “Conventional and unconventional geothermal resources: Advances in integrated approaches for exploration and monitoring” focused on case studies and innovative development of integrated exploration and investigation of geothermal reservoirs. Industrial development of geothermal resources, both hydrothermal and unconventional (Enhanced Geothermal System, super-hot, pressurized and co-produced, super-critical) systems, require the most advanced understanding of their properties and structural and hydrological features of the reservoir as well as the heat source, recharge areas. The integration of a large number of various data sets is a focus in research throughout the world. Integrated modelling, both as joint and constrained inversion, is also in continuous development.

The session “Numerical modelling in geothermics” was a platform for presentations regarding all kinds of numerical modelling in geothermics. It was open for studies of deep geothermal processes and near-surface applications and offered the possibility to discuss advances and difficulties in modelling geothermal processes and stimulating new ideas for future work.

The session “The role of biomass in a sustainable bio-economy: significant developments and impact on land use, climate and environmental services” assessed different aspects of biomass production and utilization at different scales, dealing with consequences of land-use change caused by increasing biomass production on environmental systems such as biodiversity, soils, water and atmosphere. The majority of all contributions within this session focused on the assessment of sustainable biomass potentials from various resources, and their potential contributions towards the further development of a bio-economy.

## 2.4 Carbon based energy

The session “European gas hydrate occurrences as a resource of natural gas: exploration, production and risks” brought together experts in these fields in order to exchange know-how and to identify knowledge gaps. Natural gas hydrates are inclusion compounds composed of water and gas, which form under elevated pressure and low temperature conditions and occur at all active and passive continental margins, also at the European continental slope. Since remarkable volumes of natural gas are bound in their clathrate structure, gas hydrates are considered to be a potential source of energy for the future. The exploration and quantification of marine gas hydrate occurrences at the European margins is still under investigation. Methods for the production of natural gas from this unconventional hydrocarbon reservoir considering potential risks are currently being developed and tested.

The session “Unconventional hydrocarbon resources: Advances and new technologies” was devoted to advances in technologies and case studies relevant to the exploitation and exploration for unconventional hydrocarbon resources.

## 2.5 Geo-storage for a sustainable future

The session “Geological CO<sub>2</sub> storage: Field methods and analysis of field data from sites and natural analogue” addressed field testing methods, analysis of field data and natural analogues of CO<sub>2</sub> storage, for the purpose of robust site characterization and monitoring of CO<sub>2</sub> storage sites.

Modelling of geological subsurface utilization in terms of chemical or thermal energy storage as well as hydrocarbon production and storage are required to ensure a safe and sustainable energy supply. Utilization of the geological subsurface, however, may induce changes in the recent hydraulic, thermal, mechanical and chemical regimes. The session “Process quantification and modelling in subsurface

utilization” aimed at the integration of experimental and numerical modelling methods for quantification and prediction of the potential impacts resulting from geological subsurface utilization.

The session “Assessment of barrier integrity in geological repositories for nuclear waste disposal and contaminant isolation” provided a new platform for the exchange of geophysical, geochemical and geotechnical knowledge for assessing the integrity of barriers and multi-barrier systems which is a crucial aspect for the assessment of subsurface technologies. For the storage of thermal energy and other energy carriers, or the deposition of high-level nuclear or chemo toxic waste, different repository concepts in diverse geological candidate formations such as rock salt, clay stone and crystalline rock are being discussed. Computational methods and numerical simulations, in conjunction with experimental studies across scales from micro-scale to field scale, are an integral part of safety and environmental-impact assessment concepts involving barrier integrity as a key component. Reliable comparative analyses of potential technological options require physical models capturing the individual particularities of each rock type and associated geotechnical repository and barrier concept to a comparable level of sophistication.

## 2.6 Thermal-hydro-mechanical and chemical processes related to geoenergy

Thermal, hydraulic, mechanical and chemical (THMC) processes in geological settings are of increasing interest in different geo-scientific fields. This is especially the case within current research applied to exploration and usage of natural and mineral resources from the underground. The session “Evaluation of coupled THMC processes related to geo-energy applications: from laboratory to reservoir scale” provided a scientific platform to present and discuss studies focused on various kinds of processes relevant for geo-energy related applications.

The session “Fracture, mechanics and flow in tight reservoirs” dealt with the arrangement and mechanical evolution of natural and induced fracture networks and their response to fluid flow in low-permeability rocks on a multitude of scales. The presence of fractures, whether natural or induced, has become increasingly important in recent years in the exploitation of Earth’s natural resources. Especially in rocks that have a low matrix permeability, the presence of fractures is critical for reaching flow rates sufficient for economic hydrocarbon production and heat extraction for geothermal reservoirs. Better prediction of subsurface fracture arrangements and their mechanical and flow response have become an increasingly relevant field of research.

## 2.7 Geo-materials from natural resources

Construction materials like natural stone, aggregates, bricks, cement, lime and clay form a wide and heterogeneous group which deserves attention from the scientific community due to their long-term use, importance for the society and sensitivity to the environment, e.g. the required energy during production. Most of the geo-materials have been also used in important monuments of the World Cultural Heritage. However, our knowledge of many aspects of these materials is still rather limited. Hence, the session “Geomaterials in construction: resources, properties, performance, environmental interactions, decay, and extractive industries waste management” focused on thorough discussions, e.g. of the characterisation of traditional raw materials and their products, as well as the recovery of traditional and historic knowledge of their processing and use.

## 3 Conclusion

Within this sixth ERE special issue, exciting results from research and development projects in the fields of energy, resources and the environment are presented. The common theme is how to provide affordable, reliable and sustainable energy and other georesources. Interdisciplinarity, as provided by the ERE division, is a key approach to meet these challenges of the future.

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