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Energy, Resources and the Environment: Meeting the challenges of the future

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Abstract

The European Geosciences Union (EGU) brings together geoscientists from all over the world covering all disciplines of the Earth, planetary and space sciences. This geoscientific interdisciplinarity is needed to tackle the challenges of the future. One major challenge for humankind is to provide adequate and reliable supplies of affordable energy and other resources in efficient and environmentally sustainable ways. This Energy Procedia issue provides an overview of the contributions of the Division on Energy, Resources & the Environment (ERE) at the EGU General Assembly 2017.

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Keywords: energy; resources; environment; integrated studies; exploitation; non-carbon based energy; carbon-based energy; geo-storage; geo-materials

1. Introduction

The EGU General Assembly 2017 was held from 23-28 April 2017 in Vienna, Austria. The total number of participants was 14,496 scientists of which 53% were under the age of 35 years. They came from 107 countries and

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joined 649 unique scientific sessions, 88 short courses and 322 side events. Presentations were given in the form of 11,312 posters, 4,849 orals and 1,238 interactive content (PICO).

The EGU scientific activities are organized through divisions encompassing all studies of the Earth, its environment and of the solar system in general. The 2017 scientific program of the Division on Energy, Resources & the Environment (ERE) included six subprograms:

- Integrated studies,
- Impact of energy and resource exploitation on the environment,
- Non-carbon based energy,
- Carbon based energy,
- Geo-storage for a sustainable future,
- Geo-materials from natural resources.

The ERE division hosted 19 sessions and co-organized another 14 with other divisions. In total, 529 presentations came from the ERE division in the lead, corresponding to 3% of all contributions at the EGU General Assembly 2017. This special issue includes a collection of contributions, comprising a variety of topics that were presented in the ERE sessions [1]. Comparable overview issues were published in Energy Procedia in previous years [2-5].

2. Integrated studies

The subprogram "Integrated studies" contained four sessions with ERE in the lead. The first one on "***Energy, Resources & the Environment***" provided an overview of the interdisciplinarity of the ERE division needed to tackle the challenges of the future. One of the main challenges is to provide adequate and reliable supplies of affordable energy and other resources, obtained in efficient and environmentally sustainable ways, essential to economic prosperity, environmental quality and political stability around the world.

The session "***Energy and environmental system interactions - Policy and modelling***" addressed the fact 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 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 multidisciplinary session discussed novel approaches for analyzing energy and Earth/environmental systems interactions and their implications for policy and society.

The session "***Fracture, mechanics and flow in tight reservoirs***" presented the results of experimental, numerical and field studies on fracture network formation and control on fluid flow of naturally- and hydraulically-fractured systems. Better prediction of subsurface fracture arrangements and their mechanical and flow response has become an increasingly relevant field of research.

The session "***Securing sustainable supplies of mineral resources for the low carbon economy***" highlighted the challenges to sustainable mineral exploration in developed and developing economies and the critical role that partnership working and community engagement can play.

3. Impact of energy and resource exploitation on the environment

With the subprogram "Impact of energy and resource exploitation on the environment", ERE was in the lead for two sessions. The first one on "***Environmental impacts of hydraulic fracturing: Measurements, monitoring, mitigation and management***" emphasized that the accelerated growth of oil and gas production from shale formations is accompanied by growing public concern on the environmental impacts. These concerns are related to hydraulic fracturing, required for oil and gas production from unconventional reservoirs, like, e.g., shale gas. This session presented studies from all over the world, where environmental impacts of hydraulic fracturing were measured and monitored. Scientists from various disciplines discussed the numerous processes that control the environmental impacts which shale gas exploitation and production will or may have on the subsurface, surface and atmosphere.

Recent decreases in the world oil/gas reserves imply that energy producers and consumers are facing a major challenge. The session "***Petroleum exploration and production and their impact on the environment***" dealt with enhanced exploration and production strategy needs to sustain the world energy production level. To ensure sufficient energy production levels, new advances in oil and gas exploration and production technologies are required as well as an improved understanding of their associated environmental risks and economic benefits.

4. Non-carbon based energy

The subprogram "Non-carbon based energy" contained six sessions led by ERE. The session "***Energy meteorology and spatial modelling of renewable energies***" was based on the fact that wind and sun are the predominant new sources of electrical power in recent years. Solar power reached a milestone of providing 50% of energy 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 energy generation depend on weather and climate. Modelling and measurement for resource assessment, site selection, long-term and short-term variability analysis and operational forecasting for horizons ranging from minutes to decades are of paramount importance.

The contributions in the session "***Marine renewable energy; resource characterization, interactions and impacts***" stressed that there is a global need for low-carbon energy, and marine renewable energy could make a significant contribution to reducing greenhouse gas emissions and mitigation of climate change, as well as providing a high-technology industry. Marine renewable energy includes offshore wind, wave, tidal range, and tidal-stream energy. Understanding the environment these marine renewable energy devices are likely to operate in is essential when designing efficient and resilient solutions. Furthermore, accurately charactering the resource, and its likely impacts, is essential for the development of the marine renewable energy industry.

The third session dealt with "***Conventional and unconventional geothermal resources: Advances in integrated approaches for exploration and monitoring***". The industrial development of geothermal resources, both hydrothermal and unconventional (Enhanced Geothermal System, super-hot, pressurized and co-produced, super-critical) systems, requires an advanced understanding of their properties (e.g., thermo-physical and petro-physical conditions, fluid composition, etc.) and structural and hydrological features of the reservoir as well as the heat source and recharge areas. The integration of a large number of various data sets is being carried on at many places in the world. Integrated modelling, both as joint and constrained inversion, is also in continuous development.

The session "***Numerical modelling in geothermics***" provided a platform for all studies of this kind, including those on deep geothermal processes and near-surface applications. The contributions addressed all development and operational phases of geothermal projects: prediction of geothermal potentials, optimization of borehole locations as well as the study of processes in existing geothermal installations.

"***The role of biomass in a sustainable bio-economy: implications for land use, climate and environmental service***" was presented in a separate session. The recent outcomes of the United Nations Framework Convention on Climate Change, 21st Conference of the Parties (COP21) in Paris and a range of national status reports on climate change vulnerabilities deliver a clear message to the scientific community and policy makers. We are in need of clean and renewable sources of energy and raw materials to move towards a bio-economy in various sectors. Since most renewable resources are available on the soil-atmosphere interface rather than below ground, we can expect major impacts on land use, and therefore all related subsequent issues, such as biodiversity, environmental services etc. This applies especially to biomass production and utilization, and therefore potential benefits and challenges with increased biomass production on the environment were highlighted.

One of the main challenges today is to meet the energy needs of our society in a sustainable way. Given the variability of important renewable energy sources such as sun and wind, systems exploiting these sources should be designed and operated as components of an integrated whole, where hydropower can function as a reliable stand-by source. This need for integration is also present in other areas, where natural systems serve as vital resources for society. In a world where climate variability and changing societal needs place increasing demands on the flexibility and adaptability of operational systems, the session "***Renewable energy and environmental systems: modelling, control and management for a sustainable future***" explored new methods for the design and operation of systems that depend on natural resources. Tools needed in this context are: (i) models of both environmental systems and of

management practices that can be used to study the effects of new designs and control algorithms, (ii) adaptive and resilient ways of setting goals for the operational management of environmental systems, (iii) control systems to implement these goals and (iv) ways to ensure that our goals and control systems exploit synergies and avoid potential conflicts for multi-resource and multi-sector systems.

5. Carbon based energy

The subprogram "Carbon based energy" comprised two ERE-led sessions. The one on "***Mechanics and flows in shale rocks: properties and processes***" considered the rapid rise of shale gas production which has challenged our understanding shale rocks as potential reservoirs. The need for fracturing practically impermeable rock requires involving geological, geomechanical, and hydrological integrated studies. Industry has undertaken exceptional efforts to characterize shale heterogeneity and anisotropy in unprecedented detail, highlighting the complex nature of shale properties. Despite a rather simple structure of shale reservoirs, large stress variations may develop, with important implications for both fracking design and flow modelling. Key challenges include (i) integrated analyses of shale samples coming from boreholes or from outcrops, (ii) determination of the mechanical stratification and anisotropy in shale reservoirs and their correlation with mineralogical composition and other petrophysical properties, (iii) upscaling of structural and stress-induced anisotropy of mechanical parameters of shale rocks, (iv) characteristics of mechanical and structural barriers as well as drivers for hydraulic fracture propagation, (v) stress state in shale formations and its response to stimulation treatment, (vi) transport phenomena from nanopore diffusion, leakage through micropores and microfractures up to flow in propped fractures and (vii) CO_2 behavior in shale reservoirs.

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. As the production strategies for these unconventional resources differ significantly from those applied in conventional reservoirs, advances in existing technologies and development of new technologies are needed.

6. Geo-storage for a sustainable future

The subprogram "Geo-storage for a sustainable future" contained three sessions with ERE in the lead. The session "***The future of geo-energy: understanding the subsurface for safer energy production and storage***" considered that securing future energy supply is becoming a concern at both, the global and local scales, with more often targeting unconventional reservoirs or environmentally sensitive and densely populated areas for exploitation. However, energy production removes the Earth's subsurface from its natural equilibrium, both chemically and physically. This frequently induces reservoir compaction, surface subsidence, induced (micro)seismicity and other technical and societal issues. At the same time, attempts are being undertaken to reduce CO_2 emissions via a sustainable energy transition from high-carbon fossil fuels such as oil and coal, towards cleaner energy production using geothermal energy and natural gas. The latter can potentially be combined with long-term CO_2 storage in depleted hydrocarbon reservoirs, saline aquifers or coal seams. To comply with fluctuating energy demands, energy storage in rock caverns in the form of thermal energy, compressed air, natural gas or hydrogen is a possibility. The understanding of the underlying physical and chemical processes, which control the behaviour of the subsurface, is of crucial importance for a better understanding of production-induced effects and mitigation options.

The session "***Geological CO_2 storage: Field methods and analysis of field data from sites and natural analogues***" addressed the following issues of importance for the purpose of robust site characterization and monitoring of CO_2 storage sites: (i) regional and local characterization of storage formations and their behaviour during CO_2 injection and storage, (ii) identification and determination of key site parameters for CO_2 storage such as parameter for trapping, (iii) characterization of the cap rock and its properties and (iv) analysis of natural analogues of CO_2 storage.

The importance of "***Process quantification and modelling in subsurface utilization***" was presented in a further session. 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. Therefore, this session integrated experimental and numerical modelling methods for the quantification and prediction of the potential impacts resulting from geological subsurface utilization.

7. Geo-materials from natural resources

The subprogram "Geo-materials from natural resources" comprised two ERE-led sessions. The first one was on "***Geomaterials in construction: resources, properties, performance, environmental interactions, decay, and extractive industries waste management***". Construction materials include, e.g., natural stone, aggregates, bricks, cement, lime and clay, which form a wide and heterogeneous group. Most of the geomaterials have been used in important monuments of the World Cultural Heritage. However, our knowledge of many aspects of these materials is still rather limited and needs to be improved due to their long-term use, importance for the society and sensitivity to the environment.

The second session "***Natural stone research and Heritage stone designation***" considered natural stones, which are the main material used in architectonic heritage. This session was promoted by the newly recognized "Global Heritage Stone Resource" subcommission, an International Union of Geological Sciences (IUGS) subcommission within the Geoheritage Commission. This designation seeks international recognition of those natural stone resources that have achieved widespread utilization in human culture.

8. Conclusions

The ERE division[1] of the EGU is concerned with the humankind's greatest challenges: providing sustainably acquired, reliable and adequate supplies of affordable energy and other georesources. Meeting these challenges is essential to ensure the world's economic prosperity, environmental quality and political stability. The need for answers to these interconnected challenges of energy, resources and the environment is what drives our work. The ERE division provided an interdisciplinary and in-depth program for the EGU's General Assembly 2017 of which a collection of contributions is assembled within the present issue.

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