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## Sustainable Supply of Resources and Energy is a Challenge

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### Abstract

The European Geosciences Union brings together geoscientists from all over Europe and the rest of the world, covering all disciplines of the earth sciences. This geoscientific inter- and multi-disciplinarity is needed to tackle the challenges of the future. A major challenge for humankind is to provide adequate and reliable supplies of affordable energy and other resources. These should be obtained in environmentally sustainable ways, which is essential for economic prosperity, environmental quality and political stability around the world. This issue gives a general overview of contributions during the General Assembly 2015 in the division for Energy, Resources & the Environment.

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### 1. Introduction

An aim of the division Energy, Resources & the Environment (ERE) at the General Assembly 2015 of the European Geosciences Union (EGU) in Vienna, Austria, from 12-17 April was to give an overview of the inter-and

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multi-disciplinarity inherent within this part of the EGU, which is needed to tackle the challenges of the future. Adequate and reliable supplies of affordable energy and other resources are required, obtained in environmentally sustainable ways, to provide economic prosperity, environmental quality and political stability around the world.

We set up a programme to investigate our field of studies from a variety of angles. With regard to the following themes we received contributions for this issue of Energy Procedia: integrated studies, impact of energy and resource exploitation on the environment, non-carbon based energy, carbon based energy, geo-storage for a sustainable future and geo-materials from natural resources. Of a total of around 400 papers, which were presented in Vienna in almost 25 sessions, we have collected here some 80 contributions comprising a variety of topics. Comparable issues were published in Energy Procedia in previous years [1-2].

## **2. Integrated Studies**

### *2.1. Energy resources and the environment in policy*

The Energy Resources & the Environment Division encompasses a wide range of topics that directly impact governance and policy. Therefore our aim is to bring together policymakers, governmental agencies and researchers both in academia and industry in order to tackle current and future societal challenges. Within this regard we deal with topical geoscience themes, ranging from current government practices or recommended best practices, relevant scientific evidence through examples of (geo) science based policymaking.

### *2.2. Fractures, mechanics and flow in tight reservoirs*

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.

### *2.3. Swelling rock and swelling clay*

Water inflow into clay, clay rock and clay-sulphate rock can trigger swelling phenomena. The swelling of clay-sulphate rock containing the mineral anhydrite causes large engineering problems in tunnelling and road construction in terms of floor heaves and destruction of the lining, posing a severe threat to important infrastructure. Recently, this swelling problem arose also in a different setting: The implementation of geothermal installations caused swelling ground with high uplift rates, leading to dramatic damage in the town of Staufen (Germany). The swelling of clay and clay rock has important implications for highly toxic waste disposal. Engineered barriers (i.e. the sealing and buffer elements) used in repositories play a major role in retarding any possible flow and transport of substances in the beginning of operation of the repository. Bentonites and their mixtures with granular materials have been often suggested as ideal candidates for this function. After that, natural barriers (i.e. the host rocks) will take over the role. In view of this, it is important to investigate the behaviour of the materials that have been proposed as sealing and buffer elements as well as the behaviour of the host rock, including their swelling behaviour.

## **3. Impact of energy and resource exploitation on the environment**

### *3.1. Social-ecological interactions in the Earth System: land, water and ecosystem use, planetary boundaries and sustainability transitions*

Human actions play an increasing role in shaping the Earth's planetary environment, altering the interplay between the physical climate, land surface, oceans and life, at different spatial and temporal scales. These ecosystem changes are in turn affecting socio-economic performance and human wellbeing around the world. To understand

and (where possible) predict the co-evolution of the Earth system and human actions, to characterize risks of critical ecosystem transitions, to propose planetary boundaries for the sustainability ‘playing field’, and to evaluate potential new solutions for preventing, avoiding or mitigating the anticipated impacts of global changes, we need to radically improve our understanding and description of the interactions and feedbacks of societal, climatic and environmental change.

#### **4. Non-carbon based energy**

##### *4.1. Energy Meteorology*

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 occasionally exceeds 100% of demand in Denmark. By their very nature, wind and solar power, as well as hydro, tidal, wave and other weather dependent renewable forms of generation are dependent on weather and climate. Modelling and measurement for resource assessment, site selection and operational forecasting for horizons ranging from decades to minutes are of paramount importance. The success of wind power means that wind turbines are increasingly put in sites with complex terrain or forests, with towers extending beyond the strict logarithmic profile, and in offshore regions that are difficult to model and measure. Major challenges for solar power are accurate measurements and the short-term prediction of the spatiotemporal evolution of the cloud field. For both solar and wind power, the integration of large amounts of renewable energy into the grid is another critical research problem due to the uncertainties linked to their forecast. Of particular interest these days is the field of urban meteorology applied to the renewable energy sector. The urban energy field is quite new, but there are several “smart cities” and “smart grids” projects in Europe focusing on urban measurement development for forecasts or resource mapping.

##### *4.2. Exploration, development and production of geothermal resources*

Energy from deep geothermal resources plays an increasing role in many countries in their efforts to increase the proportion of renewables in their energy portfolio. Deep geothermal heat and electric power have a high load factor, are sustainable and environmentally friendly. Even regions with moderate geothermal gradients are today considered to have a high geothermal potential, however, deep drilling is required to reach temperatures high enough for economic exploitation of the geothermal reservoir. The safe, sustainable and economic development of deep geothermal resources, also in less favourable regions, faces a number of issues requiring substantial research efforts: (1) the probability of finding an unknown geothermal reservoir has to be improved; (2) drilling methods have to be better adapted and developed to the specific needs of geothermal development; (3) the assessment of the geothermal potential should provide more reliable and clear guidelines for the development; (4) stimulation methods for enhanced geothermal systems (EGS) have to be refined to increase the success rate and reduce the risk associated with induced seismicity; (5) operation and maintenance in aggressive geothermal environments require specific solutions for corrosion and scaling problems; and (6) emerging activities to harness energy from supercritical reservoirs would make significant progress with qualified input from research.

##### *4.3. Geothermal energy from deep sedimentary basins and their basement - exploration, exploitation, characterization and modelling*

Sedimentary basins like e.g. the North German and Polish Basin, the Pannonian basin or the Upper Rhine Graben have a high geothermal potential, even though geothermal gradients are moderate. To reach geothermal reservoirs of sufficiently high temperatures for economic exploitation, deep drilling is necessary. There are many examples where aquifers are used successfully for the geothermal production of heat and also electricity. However, the exploitation of low permeable sedimentary layers is not advanced yet and needs further efforts in research and development. Of special interest are the roles of fault zones as well as crystalline rocks beneath sedimentary basins as potential geothermal reservoirs. It is necessary to optimize exploration, characterization and modelling of the Geothermal

reservoir and possible fault zones prior to drilling and to better understand physical, hydraulic and chemical processes during operation.

#### *4.4. Development of strategies towards a sustainable intensive thermal use of the shallow subsurface*

In consideration of the ongoing shift towards an energy supply from renewable sources, the thermal use of the shallow subsurface including heat generation, cooling, and thermal energy storage is increasingly gaining importance. A spatial planning of the subsurface must be developed to prevent over-exploitation of the shallow geothermal potential and to avoid conflicts with other subsurface usages. To achieve this, the shift from shallow geothermal regulation to management will be essential. However, this step preconditions a thorough geothermal process and system understanding, especially in urban areas.

#### *4.5. Sustainable biomass for raw materials, energy and GHG mitigation*

The total amount of bioenergy utilized for energy production is growing annually. Soils as the primary resource for the production of these renewable forms of energy are not renewable which implies the need of sustainable management. Fertilization and potential greenhouse gas emissions, water management (irrigation) and other ecological concerns (e.g. biodiversity) have to be considered. A sustainable efficiency enhancement is inevitable, in particular in developing countries, as the potential to convert additional land for agriculture is limited and the long-term impact on soil fertility has to be assessed. Biomass from various sources such as forests, short rotation woody crops (SRWC) and agriculture recently received increased attention. Agricultural crops are worldwide seen as an alternative resource of energy and as raw material for industrial processes (e.g. in the production of starch products and bioplastic, “second-generation products”). New approaches of thermal utilization of biomass (e.g. torrefaction, pyrolysis) are emerging and have the potential to further decrease GHG emissions via BECCS (Bio Energy and Carbon Capture and Storage). The quantification of GHG emissions on an urban / regional scale is of crucial interest to academic researchers, government agencies, non-governmental organizations, and industry, since the identification and quantification of GHG emissions enables policy makers to make informed, metrics-based decisions and to incentivize changes in transportation and land use patterns. Therefore, measurement at emission hotspots (e.g. urban structures), especially measurements of GHGs such as methane for which emissions inventories are highly uncertain, plays a crucial role in public policy discourse.

#### *4.6. Harnessing the resources offered by sun, wind and water: control and optimization*

As the awareness of the changeability of climate and society grows, importance of models of both systems and of management practices that can accommodate unexpected changes become more important. There are two aspects to this:

- the process of setting the goals for the management of environmental systems needs to be more responsive to unexpected changes, and
- the implementation of the tracking of these goals by the system in terms of manual or automatic control needs to be able to cope with unexpected changes.

The first point creates a need for faster optimization algorithms and for faster models, for instance simplified dynamic models of hydrological systems, statistical process emulators or surrogate models (e.g. linear or non-linear regression) based on data to be used in the optimization algorithms. The uncertainty about the physical processes and the complexity of the optimization problems imply that stochastic approaches deserve special attention. The second point can be addressed through techniques developed in the field of control theory.

## 5. Carbon based energy

### 5.1. Petroleum exploration and production and their impact on the environment

With an ever-expanding global population and more pressing demands for energy, conventional energy sources such as fossil fuels continue to play a large role in the energy supply chain. Recent decreases in the world oil/gas reserves imply that energy producers and consumers are facing a major challenge. Therefore, an aggressive exploration and production strategy needs to be carried out to sustain the world energy production level. With production shifting from easy to deplete reservoirs, either onshore or offshore, we are now more and more looking into more challenging locations from oil and gas, such as the Arctic region and deep water sites. This may make the impact of production on the environment substantial, in the case of an accident such as illustrated by the aftermath of the Macondo/Deepwater Horizon event in the Gulf of Mexico.

### 5.2. Unconventional hydrocarbon resources: advances and new technologies

With the depletion of more conventional reservoirs, unconventional hydrocarbon resources such as shale gas and tight sands are becoming an important source of energy with increasing demand for them in the last years. The production strategies for these unconventional oil and gas sources differ significantly from the 'old ways'. New technologies and advances in existing methods need to be made to be able to produce these reservoirs.

## 6. Geo-storage for a sustainable future

### 6.1. Gas storage and unconventional hydrocarbons: petrophysical, mechanical and chemical laboratory studies

Subsurface flow of CO<sub>2</sub> through saline and hydrocarbon reservoirs exhibits distinct phase behaviour, chemical reactivity and petrophysical flow properties. Unconventional gas/oil reservoirs (tight sandstones, shales, coals) are best characterised by lithologies that often need stimulation (e.g. fracking, drilling of deviated wells) to reach economical production rates. Both systems have in common that the design and conduction of experiments is highly challenging as the researcher has to handle either a strongly reactive fluid-rock system or a contrasting pore system (fracture versus very low matrix flow rates). The primary risk associated with both systems is the potential leakage of CO<sub>2</sub>/CH<sub>4</sub> and saline/waste water to the shallower subsurface, i.e. the contamination of drinking water reserves, which could be caused by the reactivation of pre-existing fault systems or the deterioration of the barrier rocks. Another unknown in designing a storage/production site is the development of the petrophysical properties of the reservoir rock due to long-term contact with reactive fluids or due to the fracking process. An improved understanding of the petrophysical and fluid transport properties is essential to optimise strategies to ensure a safe and environmentally friendly CO<sub>2</sub> storage and hydrocarbon production.

### 6.2. Field methods and analysis of field data for CO<sub>2</sub> geological storage

Field testing methods and analysis of field data, as part of site characterization and monitoring of CO<sub>2</sub> storage sites is a complex and diverse task. Of importance in this regard are (1) regional and local characterization of storage formations and their behaviour during CO<sub>2</sub> injection and storage; (2) identification and determination of key site parameters for CO<sub>2</sub> storage, such as parameter for trapping; and (3) characterization of the cap-rock and its properties.

### 6.3. Modelling underground environmental processes resulting from energy-related subsurface utilization

Modelling of underground storage sites is required for the efficient and safe operation as well as the assessment of site-specific risks. This requires (1) implementation of static geological/structural models; (2) determination of the relevant model scales depending on the simulated scenario (plume evolution, pressure propagation, brine displacement, etc.); (3) model and parameter upscaling techniques for multi-phase flow problems (also related to

geochemistry and geomechanics); (4) development and/or employment of (semi-)analytical and numerical modelling tools; (5) model coupling addressing the interaction of thermal, multi-phase flow, geochemical and geomechanical processes; (6) methods for risk assessment; (7) tools for operational support; and (8) benchmarks of models against operational site data and laboratory data.

## 7. Geo-storage for a sustainable future

### 7.1. Challenges to supply, quality and durability of geo-materials used in construction

Construction materials (natural stone, aggregates, bricks, cement, lime, clay, etc.) form a wide and heterogeneous group (both from the genetic and technological point of view), which deserves attention from the scientific community due to their long-term use, importance for the society and sensitivity to the environment. 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.

### 7.2. Natural stone research and heritage stone designation

At the 34<sup>th</sup> International Geological Congress in Brisbane, the “Heritage Stone Task Group” was created to facilitate formal designation to those natural stone types that have achieved important use and have been accorded significant recognition in human culture. Their recognition will promote public and policy-maker interest in stone built heritage, encourage the use of local natural stone and ensure the availability of the natural stone required for the maintenance of the built heritage and the quality of new buildings. The outcome will be the designation of a “Global Heritage Stone Resource”, meaning a natural stone of local, regional or/and other different geographical levels importance.

## 8. Conclusions

The ERE division of the EGU is concerned with one of humankind’s greatest challenges: providing sustainably harvested, reliable, and adequate supplies of affordable energy and other resources. Overcoming this challenge 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<sup>†</sup> provided an interdisciplinary and in depth programme for the EGU’s General Assembly 2015<sup>‡</sup> of which a collection of contributions is assembled within this issue covering the topics described above.

## Acknowledgements

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<sup>†</sup> <http://www.egu.eu/ere/>

<sup>‡</sup> <http://meetingorganizer.copernicus.org/egu2015/sessionprogramme>