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Energy, Resources & the Environment: Current status

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Abstract

The EGU gathers geoscientists from Europe and the rest of the world, covering all disciplines of geosciences. Geoscientific interdisciplinarity is needed to tackle future challenges. A major challenge regards the provision of adequate and reliable supplies of affordable energy and resources obtained in environmentally sustainable ways, which are essential for economic prosperity, environmental quality and political stability around the world. One goal of the ERE division is to be a leading discussion forum for these subjects. The contributions in this issue present some of the challenges that were presented in the ERE division at the EGU General Assembly in 2014.

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1. Introduction

The 2014 European Geosciences Union (EGU) General Assembly in Vienna (27 April to 2 May) had over 15000 contributions presented by nearly 12500 participants from 106 countries. Within the Energy, Resources & Environment (ERE) division there were 377 contributions presented in 19 sessions along with over 200 additional contributions that were associated with the ERE (co-listed or co-organized). All presentations touched upon aspects that concern the ERE division, varying from very detailed studies of a specific problem to a general overview of global challenges.

In this special issue, 60 of the presented contributions are summarized. Subjects dealt which include wind, solar and hydropower, geothermal energy, power, hydrocarbon exploration and production, use of sustainable biomass, geological storage of CO_2 and other gases, geomaterials and environmental monitoring. We hope that this collection

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of papers will be useful as documentation of the ERE activities at the EGU General Assembly and as a reference source for emerging research within the fields of energy, resources and the environment.

2. Integrated studies

Interdisciplinarity in studies of the natural world around us is important since we derive energy from resources and we use resources to make the planet we live on more comfortable for ourselves. Without a doubt, these activities affect the environment, and the balance between energy, resources and environment is one of the grand challenges of the future. Integrated solutions are required to provide adequate and reliable supplies of affordable energy and other resources, obtained in environmentally sustainable ways, which are essential to economic prosperity, environmental quality and political stability around the world.

Our human actions play an increasing role in shaping the Earth's planetary environment, from the physical climate system to biogeochemical cycles to the functioning of the land surface. Induced changes are in turn affecting the socio-economic performance and human well-being around the planet. To understand and predict the future co-evolution of the Earth system and human actions, it is thus critical to understand the planetary boundaries of the human playing field, the socioeconomic dynamics and their interactions with climate, and the consequences for the planetary system. New solutions are needed to prevent, overcome or mitigate the turmoil processes caused by global change, resource exhaustion, and the procession of induced socio-economic impacts, calling for a transition in the way we exploit and consume the Earth's resources.

3. Wind, solar and hydropower

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. This kind of explosive growth is likely to continue in the near future. By their very nature, wind and solar power are dependent on weather and climate. Modelling and measurement for resource assessment, site selection and operational forecasting for minutes to days time horizons are of paramount importance for the success of wind and solar power integration. Continued expansion of wind power means that wind turbines will be 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 where data are scarce. 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.

Hydropower is a mature and cost-competitive renewable energy source. Because it is flexible and instantaneous, it helps stabilize rapid fluctuations between energy demand and supply. Depending on the relative capacities of the intermittent renewables and hydropower facilities, integration may require changes in the way hydropower facilities operate to provide balancing, reserves or energy storage. Moreover, non-power constraints on the hydropower system, such as irrigation water deliveries, environmental constraints, recreation, and flood control tend to reduce the ability of hydropower to integrate with variable producing renewables. In this context, energy production relies on reliable short- and long-term predictions of the temporal availability and the quality of natural resources (water, wind, solar power, etc.).

4. Geothermal energy

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. Even regions with moderate geothermal gradients are today considered to have a high geothermal potential. In Europe, such regions include the North German and Polish Basin, the Pannonian basin and the Upper Rhine Graben. To reach geothermal reservoirs of sufficiently high temperatures for economic exploitation, deep drilling is necessary in these areas. 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 is the role of fault zones, as well as the role of crystalline rocks beneath sedimentary basins, which can serve as potential geothermal reservoirs.

The safe, sustainable, and economic development of deep geothermal resources, also in less favorable 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 development of the reservoir; (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; (6) last but not least, emerging activities to harness energy from supercritical reservoirs would make significant progress with qualified input from research.

Information systems, technological investigations, improvement of deep drilling methods, numerical and analytical modelling of hydraulic and thermal properties, and better understanding of the physical, hydraulic and chemical processes during the operation of geothermal power plants are important aspects that need to be considered. In particular, numerical modelling in geothermics is important. Modelling can cover all phases of geothermal projects: prediction of geothermal potentials, optimization of borehole locations as well as the study of processes in existing geothermal installations. They can encompass all areas relevant for geothermics such as thermal, hydraulic, mechanical and chemical processes, and fracturing processes for Enhanced Geothermal Systems.

5. Sustainable biomass for raw materials and energy

Biomass was once the major source of energy until the industrial revolution mid-19th century. Biomass from various sources such as forests, short rotation woody crops (SRWC) and agriculture recently received increased attention. It becomes now an interesting option as it provides carbon-neutral energy and/or industrial feedstock which can be easily stored and hence represents an interesting candidate to compensate for irregular provision of solar and wind energy. Biomass from forests supplied thermal energy for nearly all industrial processes and for domestic needs in the past. However, extensive utilization of forest biomass led to widespread deforestations with a number of negative consequences, such as soil erosion, loss of biodiversity and pollution of clean water reserves. Affected ecosystems began to recover slowly once fossil energy sources came into play. Recovery is very slow (up to several millennia), and hence some effects of this intensive biomass extraction, like soil acidification, are still detectable. Therefore, it is essential to produce biomass using sustainable methods and a clever recycling or cascade utilization of bio-feedstocks.

Agricultural crops are worldwide seen as an alternative resource of energy and as raw materials for industrial processes (e.g. in the production of starch products and bioplastic, and so-called "second-generation products"). New approaches of thermal conversion/utilization of biomass (e.g. torrefacation, pyrolysis) are emerging and have the potential to further decrease CO_2 emissions (e.g. through biochar amendment), and therefore provide a number of potential solutions in view of current environmental problems.

6. Hydrocarbon-based energy

Potential decreases in the world oil/gas reserves imply that energy producers and consumers are facing a major challenge. Therefore, more unconventional exploration procedures and production strategies need to be carried out to sustain the world energy production level from fossil fuels until alternatives are in place. Numerous exploration technologies, as well as their associated environmental and economic benefits, need to be considered. These include seismic (high resolution 3-D seismic; -passive seismic; 4-D time-lapse imaging, etc.), high-resolution gravity and aero-magnetic surveys, exploration of unconventional oil/gas resources, remote sensing, as well as enhanced oil recovery (EOR) methods. In addition, further studies are needed on the utilization of unconventional hydrocarbon resources such as Shale Gas and Tight Sands as these are becoming an important source of energy with increasing demand for them in the last years. However, unconventional gas/oil reservoirs (Tight Sands, Shale Gas, Coal Gas) are characterized by lithologies that generally need stimulation (e.g. fracking, drilling of deviated wells) to reach economical production rates. These practices are often met with strong societal opposition, due to unwanted side-effects, like induced seismicity and leakage of fracking fluids into groundwater systems. In order to enhance societal acceptance for the exploitation of unconventional resources, it is key to better understand and predict the risk associated with production of these resources, by improving our knowledge of the petrophysical and hydrological behavior of these reservoirs.

7. Underground storage of CO_2 and other gases

Underground storage of gases is receiving increased interest, as subsurface storage of CO_2 may help in reducing anthropogenic greenhouse gas emissions, reducing the impact on climate change, while storage of natural gas, hydrogen or heat offers a solution to store excess energy for future use. Similar to unconventional systems (see Section 6), these 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). Furthermore, the primary risk associated with unconventional or storage systems is the potential leakage of CO_2/CH_4 and saline/waste water to the lower subsurface, i.e. the contamination of drinking water, which could be caused by stress changes within the system, leading to the reactivation of pre-existing fault systems or the loss of containment provided by barrier rocks, or by long-term chemical interaction of the fluids with the host rock, potentially weakening the reservoir and/or seal rocks. An improved understanding of the petrophysical and fluid transport properties is essential to optimize strategies to ensure safe and environmentally friendly long-term storage of greenhouse gases like CO_2, or short-term storage of energy sources like natural gas, hydrogen or heat.

Research into the issues of field testing methods and analysis of field data, as part of site characterization and monitoring of storage sites, is therefore an important research area. Advances in measuring techniques and their applications, advances in associated process understanding, and the role of modeling in assessing the characteristics of a potential storage site and its spatial variability are particularly important. Modeling of underground storage sites is required for the efficient and secure operation as well as the assessment of site-specific risks.

8. Geomaterials and mineral resources

Modern mineral exploration and extraction requires use of advanced technology and scientific methods. Mining today is a high-tech industry and is going to greater depths than ever before. Successful deeper exploration will require more refined and accurate models of the Earth's crust, consistent with all available geological and geophysical information, and including an understanding of the time dimension (4D). Methods need to be developed that utilize high-quality observations to generate Earth models that can serve as a basis for new exploration strategies. Exploration geophysics, geochronology, hydrology, isotope geology, mineral deposit studies, petrology, rock mechanics, seismology and structural geology are all important for developing these Earth models.

Construction materials (natural stone, aggregates, bricks, cement, lime, etc.) form a wide and heterogeneous group (both from the genetic and technological point of view), which deserve attention from the scientific community due to their long-term use, importance for society and sensitivity to the environment. Geomaterials have also been used in important monuments that are part of the World Cultural Heritage. However, our knowledge of many aspects of these materials is still rather limited and they need to be further investigated. At the recent International Geological Congress, 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 level of importance.

9. Environmental studies

The measurement of greenhouse gas (GHG) emissions, as well as health-relevant air pollutants (e.g. particulate matter, NO_x etc.) from urban centers around the world is of extreme interest to academic researchers, government agencies, non-governmental organizations, and industry. This interest is being driven by the fact that the identification and quantification of GHG emissions and other pollutants enables policy makers to make informed, metrics-based decisions and to provide incentives to change transportation and land use patterns. In addition, anticipated regulatory changes to GHG emissions requirements, as well as recent claims by the natural gas industry that natural gas is the clean fuel of the future, have given rise to even more interest. Utilizing a variety of measurement tools, including networks of analyzers, flux measurements, and measurements taken by aircraft and cars, just to name a few, knowledge about urban-scale GHG emissions is quickly growing.

Knowledge from past radioactive contamination events, such as the Chernobyl accident in 1986, and new data from the Fukushima accident (March 2011) will improve our understanding of radioactive materials and their effects on environmental contamination. Particularly useful is the Fukushima accident since it had the most dense measurement network with the most advanced instrumentation in history. These past experiences should be used in developing improved monitoring systems, including emergency time, acute sampling/measurement schemes, and remediation schemes for a potential future accident.

10. Conclusion

The ERE division of the EGU is concerned with one of humankind's greatest challenges: providing sustainably acquired, reliable, and adequate supplies of affordable energy and other resources, such as raw materials for industrial processes. 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[†] provided an interdisciplinary and in-depth program for the EGU's General Assembly 2014[‡] of which a collection of contributions is assembled within this issue that covers the topics described above.

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† http://www.egu.eu/ere/

‡ http://meetingorganizer.copernicus.org/egu2014/sessionprogramme