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Editorial

Editorial on Special Issues of Development of Unconventional Reservoirs

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1. Introduction

The energy transition to renewable energy is inevitable since fossil fuels are a finite source. In addition, there is a future need for sustainable clean energies to power our civilization. Although many countries have put in place a net-zero carbon emission plan to be attained by 2050, to achieve this ambition, unconventional gas, such as shale gas, will play an important role in supplying the world's progressively increasing energy demand. The three Special Issues on the "Development of Unconventional Reservoirs", with more than 80 research articles, have curated a good collection of works from the many scientists all around the world who have provided their invaluable contributions. There are still more research studies required to enable us to explore and produce unconventional resources more effectively and with minimum harm to the environment.

Under political, social, and environmental inspirations, the world is shifting its energy sources from fossil fuels toward forms of renewable clean energy. Indeed, human beings are now in the era of 'energy transition'. Although the energy transition is inevitable as we move towards the end of conventional and unconventional fossil fuels, some questions still remain unclear: "how long will the energy transition take?" and "during the energy transition, what type of energy source will play the most important role in supplying the progressively increasing energy demand?".

Although conceptually, it has been accepted that 2050 will be the time for net-zero carbon emissions, this does not mean that there is no requirement for the provision of any fossil fuels thereafter. Based on data provided by [1,2] , the current energy demand is around 174,000 (Terawatt-hour, TWh) (Figure 1). Crude oil, coal, natural gas, biomass, and nuclear power are the main contributors to energy, with a share of about 31%, 25%, 23%, 6%, and 4%, respectively. Renewable energies including hydropower, wind, biofuels, solar, and other renewables currently supply 11% of global energy at their maximum. A quick ballpark calculated figure shows that the current energy demand will increase to more than 230,000 (TWh) by 2050, an increase of about 61,000 (TWh). This suggests that supplying enough energy to power civilization would not be possible without fossil fuels as a major backup source of energy towards 2050 unless either a magical revolution in renewable energy or a dramatic change in human beings' lifestyles occurs.

Among fossil fuels, natural gas is relatively clean and produces the least CO_2 [3], and it can also be the source of blue hydrogen, therefore having less impact on the environment.

The above statements emphasize that unconventional gas development is an area that needs to be continued to secure our future energy demand until our technology is advanced enough to supply enough renewable clean energy for society. I am very grateful to all who contributed their valuable research articles to these three Special Issues of "Development of Unconventional Reservoirs" [4,5], addressing many aspects of unconventional resources.

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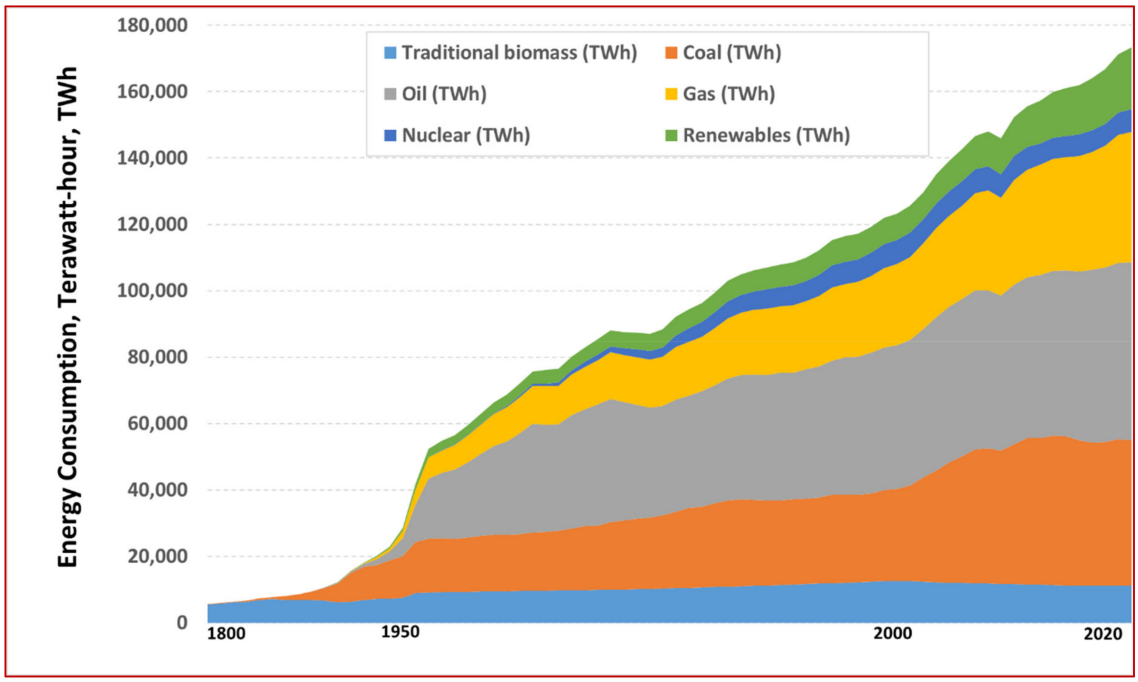

Figure 1. Global energy consumption by source (data from [1]).

2. Development of Unconventional Gas Reservoirs

Three Special Issues on the "Development of Unconventional Reservoirs" have appeared in the MDPI journal *Energies*, jointly bundling about 80 research articles. The series was started with a first call for papers in 2019 and was continued every year since. So far, three Special Issues have been published, including:

Development of Unconventional Reservoirs (https://www.mdpi.com/journal/energies/special_issues/development_unconventional_reservoirs, accessed on 30 March 2020); Development of Unconventional Reservoirs 2020 (https://www.mdpi.com/journal/energies/special_issues/development_unconventional_reservoirs_2020, accessed on 30 March 2021); and Development of Unconventional Reservoirs 2021 (https://www.mdpi.com/journal/energies/special_issues/development_unconventional_reservoirs_2021, accessed on 9 March 2022).

All three issues were edited by Prof. Resa Rezaee, Curtin University, Western Australia, who also contributed with his research group several articles to the series. The motivation to produce this special series focused on the most pressing technical challenges for developing unconventional energy sources such as shale gas, shale oil, tight gas sand, coalbed methane, and gas hydrates.

Since the subject of the Development of Unconventional gas Reservoirs was very broad, the topics covered by the submitted articles were very diverse covering some insights into shale gas plays, coalbeds, tight gas/oil sands, tight carbonate reservoirs, and gas hydrates.

The first group of papers covered some aspects of shale gas plays that include the following works:

- Comparative Porosity and Pore Structure Assessment in Shales: Measurement Techniques, Influencing Factors and Implications for Reservoir Characterization; by Yujie and Rezaee [6];
- Total Organic Carbon Enrichment and Its Impact on Pore Characteristics: A Case Study from the Niutitang Formation Shales in Northern Guizhou; by Liu, et al. [7];
- Accumulation Conditions and an Analysis of the Origins of Natural Gas in the Lower Silurian Shiniulan Formation from Well Anye 1, Northern Guizhou Province; by Guo, et al. [8];

- Volumetric Measurements of Methane-Coal Adsorption and Desorption Isotherms—Effects of Equations of State and Implication for Initial Gas Reserves; by Ekundayo and Rezaee [9];
- A Prediction Model for Methane Adsorption Capacity in Shale Gas Reservoirs; by Zou and Rezaee [10];
- Investigation of Analysis Methods for Pulse Decay Tests Considering Gas Adsorption; by Han et al. [11];
- Numerical Simulation of Gas Production from Gas Shale Reservoirs—Influence of Gas Sorption Hysteresis; by Ekundayo and Rezaee [12];
- Numerical Analysis of Transient Pressure Behaviors with Shale Gas MFHWs Interference; by Gao et al. [13];
- Performance Evaluation of CO_2 Huff-n-Puff Gas Injection in Shale Gas Condensate Reservoirs; by Meng et al. [14];
- Review of Formation and Gas Characteristics in Shale Gas Reservoirs; by Boning Zhang, Baochao Shan, Yulong Zhao, Liehui Zhang [15];
- Effect of Particle Size on Pore Characteristics of Organic-Rich Shales: Investigations from Small-Angle Neutron Scattering (SANS) and Fluid Intrusion Techniques; by Yi Shu, Yanran Xu, Shu Jiang, Linhao Zhang, Xiang Zhao, Zhejun Pan, Tomasz P. Blach, Liangwei Sun, Liangfei Bai, Qinhong Hu, Mengdi Sun [16];
- Porosity and Water Saturation Estimation for Shale Reservoirs: An Example from Goldwyer Formation Shale, Canning Basin, Western Australia; by Atif Iqbal, Reza Rezaee [17];
- Factors Affecting Shale Gas Chemistry and Stable Isotope and Noble Gas Isotope Composition and Distribution: A Case Study of Lower Silurian Longmaxi Shale Gas, Sichuan Basin; by Chunhui Cao, Liwu Li, Yuhu Liu, Li Du, Zhongping Li, Jian He [18];
- Quantitative Analysis of Amorphous Silica and Its Influence on Reservoir Properties: A Case Study on the Shale Strata of the Lucaogou Formation in the Jimsar Depression, Junggar Basin, China; by Ke Sun, Qinghua Chen, Guohui Chen, Yin Liu, Changchao Chen [19];
- Molecular-Scale Considerations of Enhanced Oil Recovery in Shale; by Mohamed Mehana, Qinjun Kang, Hari Viswanathan [20];
- Dynamic Pore-Scale Network Modeling of Spontaneous Water Imbibition in Shale and Tight Reservoirs; by Xiukun Wang, James J. Sheng [21];
- Patent Analysis on the Development of the Shale Petroleum Industry Based on a Network of Technological Indices; by Jong-Hyun Kim, Yong-Gil Lee [22];
- An Analytical Model for Production Analysis of Hydraulically Fractured Shale Gas Reservoirs Considering Irregular Stimulated Regions; by Kaixuan Qiu, Heng Li [23];
- Development and Calibration of a Semianalytic Model for Shale Wells with Nonuniform Distribution of Induced Fractures Based on ES-MDA Method; by Qi Zhang, Shu Jiang, Xinyue Wu, Yan Wang, Qingbang Meng [24];
- Experimental Investigation of the Impacts of Fracturing Fluid on the Evolution of Fluid Composition and Shale Characteristics: A Case Study of the Niutitang Shale in Hunan Province, South China; by Jingqiang Tan, Guolai Li, Ruining Hu, Lei Li, Qiao Lyu, Jeffrey Dick [25];
- Reservoir Characteristics of the Lower Jurassic Lacustrine Shale in the Eastern Sichuan Basin and Its Effect on Gas Properties: An Integrated Approach; by Jianhua He, Hucheng Deng, Ruolong Ma, Ruyue Wang, Yuanyuan Wang, Ang Li [26];
- Ensemble Learning for Predicting TOC from Well-Logs of the Unconventional Goldwyer Shale, by Partha Pratim Mandal, Reza Rezaee, and Irina Emelyanova [27];
- Stratigraphically Controlled Stress Variations at the Hydraulic Fracture Test Site-1 in the Midland Basin, TX, by Arjun Kohli and Mark Zoback [28];
- The Effect of Hydraulic Fracture Geometry on Well Productivity in Shale Oil Plays with High Pore Pressure, by Daniela A. Arias Ortiz, Lukasz Klimkowski, Thomas Finkbeiner and Tadeusz W. Patzek [29];

- Cyclic Subcritical Water Injection into Bazhenov Oil Shale: Geochemical and Petrophysical Properties Evolution Due to Hydrothermal Exposure, by Aman Turakhanov, Albina Tsyshkova, Elena Mukhina, Evgeny Popov, Darya Kalacheva, Ekaterina Dvoretskaya, Anton Kasyanenko, Konstantin Prochukhan and Alexey Cheremisin [30];
- Characteristics of Mineralogy, Lithofacies of Fine-Grained Sediments and Their Relationship with Sedimentary Environment: Example from the Upper Permian Longtan Formation in the Sichuan Basin, by Hongzhi Yang, Liangbiao Lin, Liqing Chen, Yu Yu, Du Li, Jingchun Tian, Wen Zhou and Jianhua He [31].

The second group of papers dealt with some aspects of coalbeds that include the following works:

- Experimental and Simulation Studies on Adsorption and Diffusion Characteristics of Coalbed Methane; by Kim et al. [32];
- Variation of Petrophysical Properties and Adsorption Capacity in Different Rank Coals: An Experimental Study of Coals from the Junggar, Ordos and Qinshui Basins in China; by Wang et al [33];
- Design and Evaluation of a Surfactant–Mixed Metal Hydroxide-Based Drilling Fluid for Maintaining Wellbore Stability in Coal Measure Strata; by Chen et al. [34];
- Multi-Phase Tectonic Movements and Their Controls on Coalbed Methane: A Case Study of No. 9 Coal Seam from Eastern Yunnan, SW China; by Ming Li, Bo Jiang, Qi Miao, Geoff Wang, Zhenjiang You, Fengjuan Lan [35];
- A Novel Data-Driven Method to Estimate Methane Adsorption Isotherm on Coals Using the Gradient Boosting Decision Tree: A Case Study in the Qinshui Basin, China; by Jiyuan Zhang, Qihong Feng, Xianmin Zhang, Qiujia Hu, Jiaosheng Yang, Ning Wang [36];
- Development and Performance Evaluation of Solid-Free Drilling Fluid for CBM Reservoir Drilling in Central Hunan; by Pinghe Sun, Meng Han, Han Cao, Weisheng Liu, Shaohe Zhang, Junyi Zhu [37].

The third group of papers focused on tight gas/oil sands and tight carbonate reservoirs that include the following works:

- Insight into the Pore Characteristics of a Saudi Arabian Tight Gas Sand Reservoir; by Adebayo et al. [38];
- The Characteristics of Oil Migration due to Water Imbibition in Tight Oil Reservoirs; by Yang et al. [39];
- Stress-Dependent Permeability of Fractures in Tight Reservoirs; by Cao et al. [40];
- Applicability Analysis of Klinkenberg Slip Theory in the Measurement of Tight Core Permeability; by Zou et al. [41];
- Pressure Transient Performance for a Horizontal Well Intercepted by Multiple Reorientation Fractures in a Tight Reservoir; by Xing et al. [42];
- Catalytic Effect of Cobalt Additive on the Low Temperature Oxidation Characteristics of Changqing Tight Oil and its SARA Fractions; by Wang and Wang [43]
- Controls on Pore Structures and Permeability of Tight Gas Reservoirs in the Xujiaweizi Rift, Northern Songliao Basin; by Luchuan Zhang, Shu Jiang, Dianshi Xiao, Shuangfang Lu, Ren Zhang, Guohui Chen, Yinglun Qin, Yonghe Sun [44].
- Investigation of the Pore Structure of Tight Sandstone Based on Multifractal Analysis from NMR Measurement: A Case from the Lower Permian Taiyuan Formation in the Southern North China Basin; by Kaixuan Qu, Shaobin Guo [45];
- Finite Element Simulation of Multi-Scale Bedding Fractures in Tight Sandstone Oil Reservoir; by Qianyou Wang, Yaohua Li, Wei Yang, Zhenxue Jiang, Yan Song, Shu Jiang, Qun Luo, Dan Liu [46];
- Occurrence, Classification and Formation Mechanisms of the Organic-Rich Clasts in the Upper Paleozoic Coal-Bearing Tight Sandstone, Northeastern Margin of the Ordos Basin, China; by Guanqun Yang, Wenhui Huang, Jianhua Zhong, Ningliang Sun [47];

- An Analytical Solution for Transient Productivity Prediction of Multi-Fractured Horizontal Wells in Tight Gas Reservoirs Considering Nonlinear Porous Flow Mechanisms; by Qiang Wang, Jifang Wan, Langfeng Mu, Ruichen Shen, Maria Jose Jurado, Yufeng Ye [48];
- Pore-Structural Characteristics of Tight Fractured-Vuggy Carbonates and Its Effects on the P- and S-Wave Velocity: A Micro-CT Study on Full-Diameter Cores; by Wei Li, Xiangjun Liu, Lixi Liang, Yinan Zhang, Xiansheng Li, Jian Xiong [49];
- Reservoir Properties of Low-Permeable Carbonate Rocks: Experimental Features; by Aliya Mukhametdinova, Andrey Kazak, Tagir Karamov, Natalia Bogdanovich, Maksim Serkin, Sergey Melekhin, Alexey Cheremisin [50];
- Natural Fractures in Carbonate Basement Reservoirs of the Jizhong Sub-Basin, Bohai Bay Basin, China: Key Aspects Favoring Oil Production; by Guoping Liu, Lianbo Zeng, Chunyuan Han, Mehdi Ostadhassan, Wenya Lyu, Qiqi Wang, Jiangwei Zhu, Fengxiang Hou [51].

The two following papers investigated gas hydrates:

- Research on the Estimate of Gas Hydrate Saturation Based on LSTM Recurrent Neural Network; by Chuanhui Li, Xuewei Liu [52];
- Fractional Time Derivative Seismic Wave Equation Modeling for Natural Gas Hydrate; by Yanfei Wang, Yaxin Ning, Yibo Wang [53].

The last group was classified as miscellaneous subjects that cover a variety of works dealing with some technical aspects of different unconventional plays:

- Experimental Investigation on Injection and Production Pattern in Fractured-Vuggy Carbonate Reservoirs; by He et al. [54];
- Visual Experimental Study on Gradation Optimization of Two-Stage Gravel Packing Operation in Unconventional Reservoirs; by Meng et al. [55];
- Study of Downhole Shock Loads for Ultra-Deep Well Perforation and Optimization Measures; by Deng et al. [56];
- An Automatic Classification Method of Well Testing Plot Based on Convolutional Neural Network (CNN); by Chu et al. [57];
- Study on the Impacts of Capillary Number and Initial Water Saturation on the Residual Gas Distribution by NMR; by Li et al. [58];
- Numerical Investigation of Downhole Perforation Pressure for a Deepwater Well; by Deng et al. [59];
- The Effect of Supercritical CO_2 on Shaly Caprocks; by Hadian and Rezaee [60];
- Reservoir Formation Model and Main Controlling Factors of the Carboniferous Volcanic Reservoir in the Hong-Che Fault Zone, Junggar Basin; by Danping Zhu, Xuewei Liu, Shaobin Guo [61];
- Productivity-Index Behavior for a Horizontal Well Intercepted by Multiple Finite-Conductivity Fractures Considering Nonlinear Flow Mechanisms under Steady-State Condition; by Maojun Cao, Hong Xiao, Caizhi Wang [62];
- Numerical Investigation of Injection-Induced Fracture Propagation in Brittle Rocks with Two Injection Wells by a Modified Fluid-Mechanical Coupling Model; by Song Wang, Jian Zhou, Luqing Zhang, Zhenhua Han [63];
- Proppant Transportation in Cross Fractures: Some Findings and Suggestions for Field Engineering; by Yan Zhang, Xiaobing Lu, Xuhui Zhang, Peng Li [64];
- A Novel Equivalent Continuum Approach for Modelling Hydraulic Fractures; by Eziz Atdayev, Ron C. K. Wong, David W. Eaton [65];
- Numerical Investigation on Proppant–Water Mixture Transport in Slot under High Reynolds Number Conditions; by Tao Zhang, Ruoyu Yang, Jianchun Guo, Jie Zeng [66];
- A Critical Review of Osmosis-Associated Imbibition in Unconventional Formations; by Zhou Zhou, Xiaopeng Li, Tadesse Weldu Teklu [67];
- Experimental Investigation and Mechanism Analysis on Rock Damage by High Voltage Spark Discharge in Water: Effect of Electrical Conductivity; by Zhixiang Cai, Hui Zhang, Kerou Liu, Yufei Chen, Qing Yu [68];

- Pore-Scale Lattice Boltzmann Simulation of Gas Diffusion–Adsorption Kinetics Considering Adsorption-Induced Diffusivity Change; by Zhigao Peng, Shenggui Liu, Yingjun Li, Zongwei Deng, Haoxiong Feng [69];
- Seismic Identification of Unconventional Heterogenous Reservoirs Based on Depositional History—A Case Study of the Polish Carpathian Foredeep; by Anna Łaba-Biel, Anna Kwietniak, Andrzej Urbaniec [70];
- Application of Waveform Stacking Methods for Seismic Location at Multiple Scales; by Lei Li, Yujiang Xie, Jingqiang Tan [71];
- Theoretical Comparison of Test Performance of Different Pulse Decay Methods for Unconventional Cores; by Guofeng Han, Xiaoli Liu, Jin Huang [72];
- Multidisciplinary Characterization of Unconventional Reservoirs Based on Correlation of Well and Seismic Data; by Weronika Kaczmarczyk, Małgorzata Słota-Valim [73];
- Adaptive Processing for EM Telemetry Signal Recovery: Field Data from Sichuan Province; by Olalekan Fayemi, Qingyun Di, Qihui Zhen, Yu L. Wang [74];
- Prediction of Permeability Using Group Method of Data Handling (GMDH) Neural Network from Well Log Data, by Baraka Mathew Nkurlu, Chuanbo Shen, Solomon Asante-Okyere, Alvin K. Mulashani, Jacqueline Chungu, Liang Wang [75];
- Machine Learning-Based Probabilistic Lithofacies Prediction from Conventional Well Logs: A Case from the Umiat Oil Field of Alaska; by Nilesh Dixit, Paul McColgan, Kimberly Kusler [76];
- Numerical Demonstration of an Unconventional EGS Arrangement by George L. Danko and M. K. Baracza [77];
- A Prediction Model of Pressure Loss of Cement Slurry in Deep-Water HTHP Directional Wells, by Kunhong Lv, Hao Huang, Xingqiang Zhong, Yian Tong, Xingjie Ling and Qiao Deng [78];
- Seismostratigraphic Interpretation of Upper Cretaceous Reservoir from the Carpathian Foreland, Southern Poland, by Andrzej Urbaniec, Anna Łaba-Biel, Anna Kwietniak and Imoleayo Fashagba [79];
- Study on the Mechanical Extended-Reach Limit Prediction Model of Horizontal Drilling with Dual-Channel Drillpipes, by Tianyi Tan and Hui Zhang [80];
- Design and Evaluation of High-Temperature Well Cementing Slurry System Based on Fractal Theory, by Guanyi Zheng, Xiaoyang Guo, Zaoyuan Li and Jinfei Sun [81].
- A Novel Mathematical Model Considering Real Gas PVT Behavior to Estimate Inflow Performance Relationship of Gas Well Production, by Shuang Zhang, Huiqing Liu, Yanwei Wang, Ke Sun and Yunfei Guo [82];
- Study on Annular Pressure Buildup in Offshore Heavy Oil Thermal Recovery Wells Considering Dissolved Gas Contained in Annuli, by Hao Wang, Hui Zhang, Jun Li, Anming Chen, Jun Liu, Tengfei Sun and Cong Lin [83];
- Numerical Investigation on Shape Optimization of Small-Spacing Twin-Well for Salt Cavern Gas Storage in Ultra-Deep Formation, by Haitao Li, Jingen Deng, Qiqi Wanyan, Yongcun Feng, Arnaud Regis Kamgue Lenwoue, Chao Luo and Cheng Hui [84].

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