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- 7917** DOI: 10.1021/acs.energyfuels.9b01532  
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- 7950** DOI: 10.1021/acs.energyfuels.9b00182  
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
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DOI: 10.1021/acs.energyfuels.9b01525  
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- 8202 **S** DOI: 10.1021/acs.energyfuels.9b01610  
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- 8215 DOI: 10.1021/acs.energyfuels.9b01625  
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- 8231 DOI: 10.1021/acs.energyfuels.9b01708  
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- 8241 DOI: 10.1021/acs.energyfuels.9b01716  
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- 8250 DOI: 10.1021/acs.energyfuels.9b01732  
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- 8312 DOI: 10.1021/acs.energyfuels.9b01688  
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- 8383 DOI: 10.1021/acs.energyfuels.9b01884  
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- 8394 <sup>S</sup> DOI: 10.1021/acs.energyfuels.9b01940  
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- 8403 <sup>S</sup> DOI: 10.1021/acs.energyfuels.9b01956  
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- 8413 DOI: 10.1021/acs.energyfuels.9b01983  
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- 8423 <sup>S</sup> DOI: 10.1021/acs.energyfuels.9b01950  
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- 8440 <sup>S</sup> DOI: 10.1021/acs.energyfuels.9b01993  
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- 8448 DOI: 10.1021/acs.energyfuels.9b01994  
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- 8522 <sup>S</sup> DOI: 10.1021/acs.energyfuels.9b02245  
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- 8530 <sup>S</sup> DOI: 10.1021/acs.energyfuels.9b02113  
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- 8557 <sup>S</sup> DOI: 10.1021/acs.energyfuels.9b02345  
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- 8566 DOI: 10.1021/acs.energyfuels.9b02400  
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How Anion Structures Can Affect the Thiophene Distribution between Imidazolium-Based Ionic Liquid and Hydrocarbon Phases? A Theoretical QSPR Study

Ali Ebrahimpour Gorji and Mohammad Amin Sobati\*

## Biofuels and Biomass

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Geochemical Characteristics and Geological Significance of the Anaerobic Biodegradation Products of Crude Oil

Changhai Gao,\* Yunyin Zhang, Xingmou Wang, Junzhang Lin, and Yuyuan Li

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Production of Aryl Oxygen-Containing Compounds by the Pyrolysis of Bagasse Alkali Lignin Catalyzed by  $\text{La}_{0.2}\text{Fe}_{0.8}\text{O}_3$  (M = Fe, Cu, Al, Ti)

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Kinetic Parameters for Biomass under Self-Ignition Conditions: Low-Temperature Oxidation and Pyrolysis

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Mathematical Modeling of Acetone–Butanol–Ethanol Fermentation with Simultaneous Utilization of Glucose and Xylose by Recombinant *Clostridium acetobutylicum*

Jongkoo Lim, Ha-Eun Byun, Boeun Kim, Hyerin Park, and Jay H. Lee\*

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Improving Energy Density and Grindability of Wood Pellets by Dry Torrefaction

Seunghan Yu, Jinje Park, Minsu Kim, Heeyoon Kim, Changkook Ryu,\* Yongwoon Lee, Won Yang, and Yeong-gap Jeong

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Ultrasonic-Assisted Upgrading of the Heavy Bio-Oil Obtained from Pyrolysis of Pine Nut Shells with Methanol and Octanol Solvents

Liyuan Qin,\* Ye Shao, Zhiwei Hou, Yuewen Jia, and Enchen Jiang\*

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Influence of Porosity in a Packed-Bed Tubular Reactor on Biodiesel Production from Soybean Oil and Supercritical Ethanol: An Experimental and Phenomenological Investigation

Luiz E. P. Santiago, Érica G. Rebouças,\* Maxwell G. Silva,\* Katherine C. Oliveira, Anderson A. Jesus, Emerson M. Aguiar, Jackson A. Oliveira, and Domingos F. S. Souza

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Catalytic Depolymerization of a Lignin-Rich Corncob Residue into Aromatics in Supercritical Ethanol over an Alumina-Supported NiMo Alloy Catalyst

Yunfei Bai, Kai Cui, Yushuai Sang, Kai Wu, Fei Yan, Fuhang Mai, Zewei Ma, Zhe Wen, Hong Chen, Mengmeng Chen,\* and Yongdan Li\*

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Catalytic Effect of Inorganic Elements on Steam Gasification Biochar Properties from Agrowastes

Lina María Romero Millán,\* Fabio Emiro Sierra Vargas, and Ange Nzihou

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Effects of EGR Dilution on Combustion and Emission Performance of a Compression Ignition Engine Fueled with Dimethyl Carbonate and 2-Ethylhexyl Nitrate Additive

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Continuous Steam-Assisted Low-Temperature Pyrolysis of Alkali Lignin and Selective Production of Guaiacol Components in a Fixed-Bed Reactor

Jun Ye, Minghao Zhou, Jiaping Zhao, Haihong Xia, Junming Xu, Weihong Tan, and Jianchun Jiang\*

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Adsorption Characteristics and Mechanisms of Coal–Microorganisms in the Process of Biogenic Methane Production from Highly Volatile Bituminous Coal

Daping Xia, Huaiwen Zhang, Xianbo Su,\* Hao Chen, and Dan Li

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Comparison of Anaerobic Methane Fermentation Performance and Ammonia Resistance with Different Inoculum Configurations

Ziyi Yang, Hangyu Sun, Yang Liu, Chao Liu, Ruihong Zhang, Guangqing Liu,\* and Wen Wang\*

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Modeling Carbon-to-Nitrogen Ratio Influence on Biogas Production by the 4th-order Runge–Kutta Method

Latif Fagbemi, David Adamon, and Evrard Karol Ekouedjen\*

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Copyrolysis Behavior of Xylan and Polyvinyl Chloride Plastic

Wanli Wang, Kai Sun, Mujahid Ali, Xiaojie Liu, and Qunxing Huang\*



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**Synergistic Characteristics and Capabilities of Co-hydrothermal Carbonization of Sewage Sludge/Lignite Mixtures**  
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**An Energy and Exergy Analysis of Biomass Gasification Integrated with a Char-Catalytic Tar Reforming System**  
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**Biocrude Oil Production through the Maillard Reaction between Leucine and Glucose during Hydrothermal Liquefaction**  
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**Kinetic Analysis of Dried Biosolid Pyrolysis**  
William Kreutter, Zhongzhe Liu, Patrick McNamara, and Simcha Singer\*

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**Effects of Combined Torrefaction and Pelletization on Particulate Matter Emission from Biomass Pellet Combustion**  
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**Depolymerization of Lignin over a Ni-Pd Bimetallic Catalyst Using Isopropanol as an in Situ Hydrogen Source**  
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**Anaerobic Thermophilic Digestion of Maotai-Flavored Distiller's Grains: Process Performance and Microbial Community Dynamics**  
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## Environmental and Carbon Dioxide Issues

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**Comparison of Sodium Lignosulfonate and Derived Biochar for Influencing Methane Bioevolution**  
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DOI: 10.1021/acs.energyfuels.9b00522

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**Characterization of the Fine Particle Emissions from the Use of Two Fischer-Tropsch Fuels in a CFM56-2C1 Commercial Aircraft Engine**  
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**Regenerable Ce-Mn/TiO<sub>2</sub> Catalytic Sorbent for Mercury Removal with High Resistance to SO<sub>2</sub>**  
Xiang Wu, Yufeng Duan,\* Na Li, Peng Hu, Ting Yao, Jialin Meng, Shaojun Ren, and Hongqi Wei

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**Mineral Carbonation for Carbon Utilization in Microalgae Culture**  
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DOI: 10.1021/acs.energyfuels.9b01232

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**Integrated PVT and Coreflooding Studies of Carbonated Water Injection in Tight Oil Reservoirs: A Case Study**  
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- 8927 **S** DOI: 10.1021/acs.energyfuels.9b01638  
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- 8937 **S** DOI: 10.1021/acs.energyfuels.9b01745  
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- 8946 DOI: 10.1021/acs.energyfuels.9b01771  
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- 8954 DOI: 10.1021/acs.energyfuels.9b01786  
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- 8967 DOI: 10.1021/acs.energyfuels.9b01872  
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- 8976 DOI: 10.1021/acs.energyfuels.9b01892  
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- 8985 **S** DOI: 10.1021/acs.energyfuels.9b01957  
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- 8998 DOI: 10.1021/acs.energyfuels.9b02012  
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- 9004 **S** DOI: 10.1021/acs.energyfuels.9b02117  
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- 9014 DOI: 10.1021/acs.energyfuels.9b02133  
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- 9023 DOI: 10.1021/acs.energyfuels.9b02116  
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- 9032 DOI: 10.1021/acs.energyfuels.9b02158  
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- 9040 DOI: 10.1021/acs.energyfuels.9b02226  
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- 9067 DOI: 10.1021/acs.energyfuels.9b01170  
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- 9074 DOI: 10.1021/acs.energyfuels.9b01823  
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- 9099 DOI: 10.1021/acs.energyfuels.9b01723  
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- 9107 DOI: 10.1021/acs.energyfuels.9b02200  
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- 9124 DOI: 10.1021/acs.energyfuels.9b00810  
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- 9138 DOI: 10.1021/acs.energyfuels.9b00967  
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- 9149 DOI: 10.1021/acs.energyfuels.9b01474  
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- 9161 DOI: 10.1021/acs.energyfuels.9b01516  
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- 9171 DOI: 10.1021/acs.energyfuels.9b01598  
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- 9184 DOI: 10.1021/acs.energyfuels.9b01671  
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- 9196 DOI: 10.1021/acs.energyfuels.9b01678  
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- 9205 DOI: 10.1021/acs.energyfuels.9b01711  
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- 9215 DOI: 10.1021/acs.energyfuels.9b01753  
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- 9224 DOI: 10.1021/acs.energyfuels.9b01759  
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- 9232 DOI: 10.1021/acs.energyfuels.9b01775  
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- 9241 DOI: 10.1021/acs.energyfuels.9b01908  
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- 9249 DOI: 10.1021/acs.energyfuels.9b02050  
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- 9272 DOI: 10.1021/acs.energyfuels.9b02097  
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- 9280 DOI: 10.1021/acs.energyfuels.9b02189  
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- 9289 DOI: 10.1021/acs.energyfuels.9b02249  
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- 9302 DOI: 10.1021/acs.energyfuels.9b02307  
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Preparation of Highly Porous Carbon through Slow Oxidative Torrefaction, Pyrolysis, and Chemical Activation of Lignocellulosic Biomass for High-Performance Supercapacitors

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Rezki Akkal,\* Hamidréza Ramézani,\* Mohamed Khodja, and Slimane Azzi

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Xinliang Li, Guancheng Jiang,\* Lili Yang,\* Kai Wang, He Shi, Gongrang Li, and Xiongjun Wu

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Bench-Top Thermal and Steam Catalytic Cracking of Athabasca Residual Fractions: Attainable Upgrading Levels Correlated with Fraction Properties

Lante Carbognani Ortega,\* Estrella Rogel, Maria J. Perez-Zurita, Enzo Peluso, Josune Carbognani, Cesar Ovalles, Francisco Lopez-Linares, Janie Vien, Ajit Pradhan, and Pedro Pereira-Almao

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Toward Stable Operation of Sewage Sludge Incineration Plants: The Use of Alumina Nanoparticles to Suppress Adhesion of Fly Ash

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\* Supporting Information available via online article

## Recent Advances in Heavy Oil Upgrading Using Dispersed Catalysts

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**ABSTRACT:** Unconventional feedstocks, such as heavy vacuum residue (VR), have become potential candidates that could be positively exploited to meet the increasing demand of high-value transportation fuels, in view of the growing scarcity in other energy sources. However, such feeds contain extremely high-molecular-weight species, besides many impurities of heteroatom-containing organic compounds that lead to quick fouling, poisoning, and deactivation of catalysts. This causes a significant pressure decrease during the conventional hydrocracking in ebullated- or fixed-bed reactors. In contrast, slurry-phase hydrocracking has the ability to overcome these drawbacks through the enhancement of hydrogenation reactions in the presence of the dispersed catalysts. Slurry-phase processing is a resilient technology, which employs catalysts that are generally categorized as heterogeneous solid supported catalysts and homogeneously dispersed catalysts. The dispersed catalysts are classified into water or oil-soluble types and fine powders. Soluble dispersed catalysts show higher catalytic activity, compared to finely powdered catalysts, because of the in situ formation of infinitesimally minute active metal sites at high surface-area-to-volume ratios. Recent technologies and studies on heavy oil upgrading that implement the dispersed catalysts have been reviewed. Studies using a combination of two-phase catalysts have also been included.

## 1. INTRODUCTION

The depleting supply of light crude oil and the increasing demand for high-value clean fuels has encouraged petroleum refiners to process low-value feedstocks, such as fuel oil, bitumen, and residual oils (Figure 1). One of the most critical

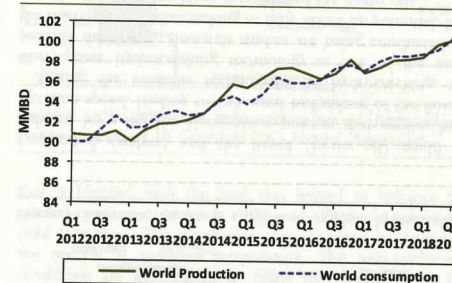


Figure 1. World's production and consumption capacity of liquid fuels. Adapted from ref 1.

issues that have accentuated the problem is the fact that the decrease in the availability of conventional crude oils, because of the massive dependence on light oil.<sup>1</sup> Consequently, the utilization of every fraction of heavy petroleum feedstocks represents the facile challenge to solve the issue of the increased demand for light transportation fuels and to reduce the dependency on conventional crude oil reserves. The source

of heavy oil can be either straight-run or produced due to thermal/catalytic processes within the refineries. Naturally, heavy oil is found in the form of a high-boiling fraction of heavy crude oil or extra-heavy crude. Moreover, the heavy oil could be produced in the petroleum refineries because of the nondestructive physical separation processes that occurs in the atmospheric distillation, as well as the vacuum distillation that produce heavy residues, such as vacuum residue (VR) and vacuum gas oil (VGO).<sup>2</sup>

The technologies implemented in the refining industry to upgrade the heavy oil can be categorized as thermal or catalytic processes. The thermal processes include delayed coking, flexicoking, visbreaking, and fluid coking.<sup>3</sup> On the other hand, the catalytic upgrading of heavy oil is accomplished through either catalytic hydrocracking or fluid catalytic cracking (FCC). In order to address the most problematic issue in heavy oil processing, which is the condensation of the polynuclear aromatics and the cause of coke formation, catalytic cracking conducted by utilizing hydrogen was a revolutionary leap and it was referred to as "hydrocracking". Catalytic hydrocracking has become an essential component for the petroleum refining industry for upgrading low-value feedstocks.<sup>3–5</sup> The hydrocracking was first introduced in Germany in 1915 to provide light valuable liquids derived from coal. In 1927, the first attempt to build a commercial hydrocracking unit was made in

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