frontiers | Frontiers in Energy Research

MINI REVIEW
published: 01 April 2022
doi: 10.3389/fenrg.2022.829398

Unconventional Oil Prospects and Challenges in the Covid-19 Era

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Fossil fuels will continue to play an important role for the forthcoming decades, including in key hard-to-abate transport and industrial sectors. Unconventional oil (UO) has emerged as a sizeable contributor to meeting the global energy demand in the energy transition period. However, unfavorable circumstances compounded by the Covid-19 pandemic have intensified uncertainties and speculation regarding the future prospects of these resources. This mini-review explores prospects and challenges faced by UO development in the Covid-19 era, focusing on technical, economic, energy security, and environmental sustainability aspects. While UOs have been significantly affected by the pandemic in the short term, limited medium to long-term UO projections exist, with contrasted findings. The review reveals the multiplicity and complexity of interactions between the Covid-19 pandemic and the discussed UO aspects, the diversity of views, and conflicting short- and long-term goals of the energy industry.

Keywords: unconventional oil, crude oil, oil price, environmental impact, energy security, COVID-19, pandemic

OPEN ACCESS

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Specialty section:
This article was submitted to Process and Energy Systems Engineering, a section of the journal Frontiers in Energy Research

***Received:** 05 December 2021*
***Accepted:** 08 March 2022*
***Published:** 01 April 2022*

Citation:
Eveloy V and Elsheikh H (2022) Unconventional Oil Prospects and Challenges in the Covid-19 Era. Front. Energy Res. 10:829398. doi: 10.3389/fenrg.2022.829398

INTRODUCTION

Despite substantial global efforts to transition away from fossil fuel-based energy sources to reduce environmental impact and address climate change, oil could still contribute up to 25–30% of the global energy mix in 2040 depending on scenario (DNV, 2017; BP, 2020). This is contributed by renewable deployment pace limitations particularly in developing economies (IEA, 2021a), and the need for energy-dense fuels in heavy/long-distance transport, as well as chemical feedstock (e.g., lubricants, plastics, fertilizers) and high-grade heat in industrial applications, with limited low-carbon alternatives in the short to medium term (BP, 2020; IEA, 2021b). Meeting demand in the context of both energy security and the foreseeable depletion of aging conventional fossil resources, has driven the development of more complex, difficultly exploitable reserves (IEA, 2021b; Manfroni et al., 2021), in particular, unconventional resources (Kryukov and Moe, 2018; Delannoy et al., 2021). Unconventional reserves have been estimated to account for up to 80% of total hydrocarbon resources (Caineng et al., 2015), with conservatively ~500–1,000 billion barrels (bbl) of recoverable unconventional oil (UO) (DNV, 2017; IEA, 2021b). The most prevalent UO types include light tight oil (LTO), heavy oil and natural bitumen (HOB/Oil Sands), deepwater oil (DO), and kerogen oil (Kapustin and Grushevenko, 2018; IEA, 2021b)[1]. UO development in the past

[1]LTO is comprised of low-density oils trapped in ultra-low permeability reservoirs, and is most prevalent in the U.S.A. (Gordon, 2012). HOB consists of dense, viscous hydrocarbon mixtures that arise as a product of conventional oil degradation, and is mostly found in Canada, South America and Eurasia (Kapustin and Grushevenko, 2018). DO refers to offshore oil reservoirs deeper than ~125 m, and is prominently found in the Gulf of Mexico and Brazil off-shore (EIA, 2016). Kerogen oil is composed of source rock laced with solid organic matter that can be turned into hydrocarbon, and found in a number of countries worldwide. However few kerogen pilot production projects are in operation due to economic, technical and ecological challenges (IEA, 2017; Kapustin and Grushevenko, 2018).

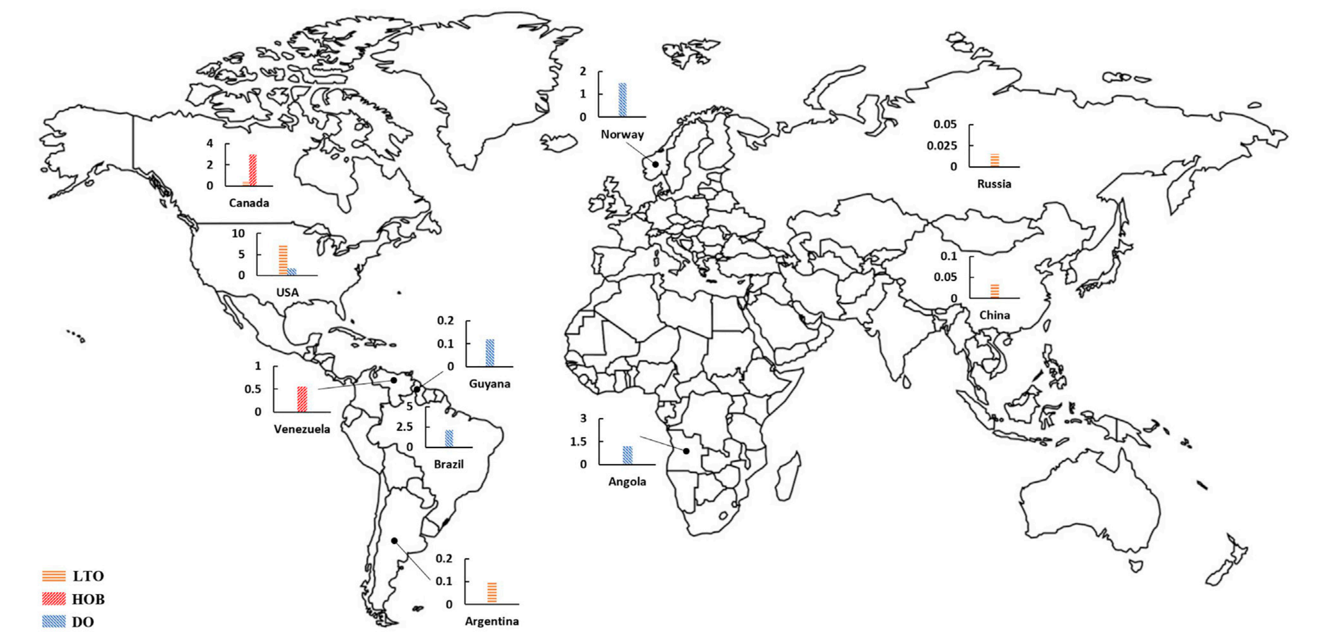

FIGURE 1 | Recent LTO, HOB, and DO production estimates in mb/d derived from (EIA, 2016; Aizhu, 2021; Astakhova, 2021; James, 2021; Mogollon, 2021; OPEC, 2021; Spencer, 2021).

2 decades has been enabled by progress in extraction technologies including hydraulic fracturing for LTO and steam-assisted gravity drainage (SAGD) for HOB, as well as favorable oil prices in the mid–2000s, which contributed to make these resources become commercially viable (IEA, 2021b). With these advances, the share of UO reached ~10% of total liquids production by 2020, from less than 5% in 2000 (DNV, 2017; IEA, 2021b). Recent UO production estimates for main exploited resources (i.e., LTO, HOB, DO) are represented in **Figure 1**. UO development, considered a revolution in the energy industry, has altered the geographies of oil and energy security (Gordon, 2012; Marlin-Tackie and Smith, 2020).

UO perceived risks and benefits diverge among scientists and the public (Marlin-Tackie and Smith, 2020). While contributing to local employment, economic growth and energy security for producers in the near-term, unconventional hydrocarbons face uncertainties in a context of increased environmental and social sustainability concerns including the rapidly diminishing world carbon budget, and competition with both conventional and rising low-carbon energy sources (Deloitte, 2021). The Covid-19 pandemic has already had profound impacts on a number of sectors including energy (Jiang et al., 2021), from economic, environmental, societal and geopolitical perspectives. The question arises whether the pandemic, compounding other recent circumstances (Delannoy et al., 2021), may have amplified global and local uncertainties impacting UO, and altered UO prospects and challenges. Recent reviews related to the Covid-19 pandemic have provided valuable insights into its impact on energy (Jiang et al., 2021) including oil (Norouzi, 2021; Quitzow et al., 2021), economy (Al-Thaqeb et al., 2020; Chenli et al., 2021), and environment and sustainability (Atoufi et al., 2021; Abubakar et al., 2021). However, none of these reviews have focused on the impacts of the pandemic on UO. This article aims to contribute a brief review of UO prospects and challenges, focusing on the observed and anticipated effects of the Covid-19 pandemic on UO economic/market aspects (*Economic and Market Aspects*), geographies and energy security (*Geographies and Energy Security*) and environmental aspects (*Environmental Aspects*).

ECONOMIC AND MARKET ASPECTS

Both prior to and during the Covid-19 pandemic outbreak, one of the most significant challenges faced for UOs' expansion has been their sensitivity to oil price instabilities contributed by economic and other unforeseen events. This sensitivity is associated with the relatively high and varied UO breakeven prices compared to conventional oils (Gordon, 2012; Kapustin and Grushevenko, 2018)[2]. OPEC's ability to adjust their budgets to lower their breakeven prices enables flexibility in responding to reductions in oil prices by controlling the supply of conventional crude and leveraging their production cost advantage when compared with unconventional resources (Kapustin and Grushevenko, 2018; IEA, 2021b).

[2]LTO had a breakeven price of \$40–\$67 per barrel (bl) in the U.S.A. in 2020 (Wigwe et al., 2020), while HOB produced using SAGD technologies had a breakeven price between \$40–\$80/bl in Canada in 2016, and the world-average DO breakeven price was estimated at ~\$55/bl in 2017 (DNV, 2017; IEA, 2021b). By contrast, Middle East OPEC conventional oil producers set their breakeven prices between \$40–\$70/bl in 2017, significantly lower than \$60–\$130/bl in 2014 (IEA, 2021b). Based on pre-pandemic projections, UO production costs of \$50–\$55/bl or lower could permit to effectively respond to OPEC interventions (DNV, 2017).

When the economic impact of the Covid-19 pandemic manifested around April 2020, an oversupply of approximately 20 million barrels of oil per day (MMbl/d) developed, pushing oil prices to below $20/bl (Mckinsey, 2021). This resulted from a rapid decline in demand for liquid fuels, which in early 2020 dropped 9 MMbl/d below 2019 levels (IEA, 2021a), due to reduced transport and industrial activities, and supply chain disruptions (BP, 2020; Le et al., 2021). This led a number of UO producers to shut down operations, thereby significantly reducing output in Spring 2020 (Crowley et al., 2020). Although oil demand has since slowly recovered, it remained 9% below 2019 levels at the end of 2020 (McKinsey, 2021), and is not expected to fully recover to 2019 levels until 2023–2025 (IEA, 2021a; McKinsey, 2021). Crude oil prices, which dropped to negative values for the first time historically in April 2020 (Le et al., 2021), partly recovered to ~$80/bl by mid November 2021. However, oil prices fell again by ~10% to ~$70/bl in a single day in late November 2021, upon discovery of the Omicron variant of Covid-19 (Ambrose, 2021). Oil prices rose again above $90/bl in February 2022, thereby placing unconventional producers in a better position to compete with conventional ones. In the near-term, oil market demand may continue to be adversely affected by insufficient vaccine deployment and the possibility of future vaccine-resistant virus variants (IEA, 2021a). Major international oil companies (e.g., BP, Chevron, Shell, Total) have recently wrote down substantial portions of their assets including more expensive and carbon-intensive unconventional fields to focus on lower-cost oil resources and shift to lower-carbon energy vectors (IEA, 2021a).

The reduction in oil prices following the Covid-19 pandemic outbreak led UO producers to pursue operations below breakeven point and to seek further improvements in efficiency in an attempt to reduce breakeven prices (Albishausen, 2020). Liabilities have further accumulated in the UO industry, with a number of bankruptcies, and increased mergers and acquisitions. Macro-economic uncertainties associated with the pandemic are thought to have been amplified by the considerable media coverage of the pandemic (Le et al., 2021). This climate has resulted in suspended/cancelled investments, and may slow global development of oil production and refining capacity over the next few years (IEA, 2021a). Investments could however be imperative to maintain market share against low-carbon technologies (Norouzi, 2021). In addition, regaining investor confidence may require efforts to focus on profitability rather than growth and market share (Albishausen, 2020), which could be facilitated by the on-going digital transformation of the oil industry (Deloitte, 2021; Elijah et al., 2021).

In the longer term, concerns of the Covid-19 pandemic having induced potentially persistent changes in consumer behavior, affecting transport fuel and industrial demand, and prompting more environmentally and socially responsible behavior, have led to question whether the oil market may return to a pre-pandemic behavior (Helm, 2020; Mulvaney et al., 2020; IEA, 2021a; Le et al., 2021). While rebounding fossil energy prices could accelerate low-carbon energy policy deployment, the pandemic may have considerably altered the economic and political context under which such policies were developed, including the European Green Deal and U.S. Green New Deal (Steffen et al., 2020). Policy constraints may have become harder to surmount, in a climate of restructuring industries, unemployment and reduced demand for goods/services including commodities; electric transportation share targets may be compromised by reduced car sales (Steffen et al., 2020). High rebound and volatility in fossil energy prices could also result in politically and socially disruptive effects slowing down low-carbon energy transitions (IEA, 2021a).

Oil markets are not assumed to return to a new normal until the pandemic has become endemic (Le et al., 2021). To accelerate recovery, measures/regulations to mitigate reduced oil demand and timely assistance to individual consumers and enterprises has been recommended (Le et al., 2021). In general, making energy policies adaptive to shocks including future pandemics has become a necessity (Steffen et al., 2020).

Historical and projected annual LTO, HOB, and DO production estimates are represented in **Figure 2**. Limited UO projections have been published since the onset of the Covid-19 pandemic. In the short-term (2025), UO shares of up to 28% have been anticipated (Hosseini et al., 2021). In the longer term, depending on scenario, UO production could grow until the early to mid 2030s, and either subsequently decline (BP, 2020; IEA, 2021b) or be maintained through 2050 (IEA, 2021b). 2030–2050 UO shares of global oil production range from 3 to 12% in (IEA, 2021a; IEA, 2021b; McKinsey, 2021), up to 50% in (Delannoy et al., 2021). Disparities in historical and projected UO production estimates between published sources are attributable to differences in UO type definitions, projection scenario assumptions (Wachtmeister and Höök, 2020), and limited information/data available related to the impacts of the pandemic.

GEOGRAPHIES AND ENERGY SECURITY

In Covid-19 pre-pandemic analyzes, UO production over the next decades has been expected to be dominated by Venezuela (sandstone), Canada (bitumen), Russia (shale oil–a sub-category of LTO) and the U.S. (tight oil) (Morozov et al., 2018). The ability of different UO producing geographies to resist the effects of the pandemic depends on local reserve characteristics, status of existing UO development, and economic and political circumstances (Jefferson, 2020). U.S. shale oil benefits from already developed infrastructure, abundant geological data, and ease of storage, which could facilitate delayed market release after oil price recovery (Kryukov and Moe, 2018; Jefferson, 2020). In response to the pandemic, investments in drilling were made in both the US and Canada (Quitzow et al., 2021). However, further U.S. UO development is challenged by environmental concerns, evidenced by previous hydraulic fracturing bans (Albishausen, 2020), and concerns of possible economic and energy security implications associated with potential new bans through 2021–2025 (United States Department of Energy (DOE), 2021). Canada's heavy oils and their unfavorable breakeven prices are compounded by the expressed drive towards a low-carbon economy (Jefferson, 2020). After being significantly

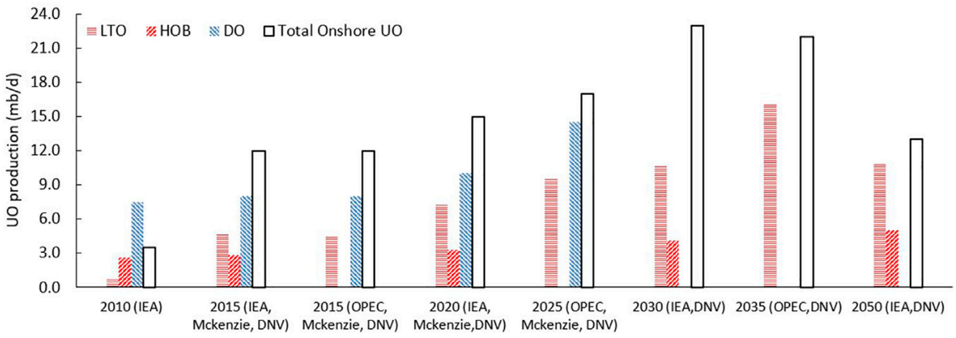

FIGURE 2 | Historical and projected annual LTO, HOB, and DO productions derived from (OPEC, 2015; IEA, 2016; DNV, 2017; Thom, 2019; IEA, 2021b; OPEC, 2021). Note: IEA data for 2020 onwards correspond to Stated Policies scenario. Mckenzie DO data derived from (Thom, 2019) include natural gas. 2035 LTO production estimates include unconventional natural gas liquids.

affected by the pandemic, Canadian UO production may rise above 2019 levels by 2026 (IEA, 2021a). Venezuela's challenges include the heavy oil characteristics of ~80% of its reserves, and political, economic and social circumstances (Jefferson, 2020), and insufficient reservoir management and investment (IEA, 2021a). Despite a huge shale oil resource potential, Russia faces challenges related to the high uncertainty of most of these resources, UO sector flexibility/responsiveness, infrastructure, technological deployment, and financial and regulatory framework (Kryukov and Moe, 2018). Importers' concerns related to Russia's crude oil quality and supply chain may have augmented during the pandemic (Jefferson, 2020). However, Russian producers are reported to have drilled but not completed wells so as to augment production rapidly when oil demand recovers from the pandemic (IEA, 2021a). The abundance of relatively light crude oil in Saudi Arabia is an advantage for recovery, but production and distribution may be exposed to future geopolitical forces (Jefferson, 2020). Despite their focus on conventional reserves, Gulf Cooperating Council (GCC) countries have recently began exploring UO (mostly shale/tight oil), local reserves of which are anticipated to be significant (Patten and Gawrych, 2019). If developed, such reserves could offer strategic market advantages to GCC producers (Patten and Gawrych, 2019). However, the 2020 fall in oil prices may have accelerated the need for economic diversification among GCC countries (Eveloy and Gebreegziabher, 2019; Arezki et al., 2020; Kabbani and Ben Mimoune, 2021).

In terms of oil demand, the Asia-Pacific region including China and India is expected to dominate growth through 2040 due to population and economic growth, including increased vehicle ownership. The pandemic has been a source of tension between the US and China, and could lead China to either emphasize energy security and rely on its coal resources, or to take a lead in low-carbon energy technologies (Oxford Energy Forum, 2020). Oil consumption is expected to decrease in Europe over the next decades due to rising sustainable energy policies (Morozov et al., 2018) including in response to the pandemic (Quitzow et al., 2021).

The pursuit of improved resilience (Fattouh, 2021) may involve deglobalization, as countries aim at reduced dependence on imported goods/services, and restoring certain domestic activities and supply chains (BP, 2020). Energy security concerns may augment, and increase unconventional development to avoid energy imports in countries possessing such reserves, while at the same time fossil energy trading may reduce (BP, 2020). The pandemic has highlighted the volatility of fossil fuel prices, potentially resulting in renewables appearing less risky (Oxford Energy Forum, 2020), although the potential future price volatility of key minerals used in clean energies could also lead to geopolitical instabilities (IEA, 2021b). Decentralized renewables may be more reliable than centralized energy sources during pandemics (Norouzi et al., 2020). However, access to renewables is geographically uneven and the pandemic may have enlarged the gap between the "*leaders and laggards*" of a global energy transition (Quitzow et al., 2021).

ENVIRONMENTAL ASPECTS

On the supply side, unconventional resource extraction, refining, and transport involve energy and natural resource (i.e., land, water) intensive processes that result in atmospheric pollution, land damage and pollution[3], surface/ground water use/pollution and waste water disposal issues, and habitat and local community disruptions (Albishausen, 2020; Marlin-Tackie and Smith, 2020). The predicted weighted-average energy return on energy investment (EROI), of oil liquids production could decline from 44 in 1950 to 6.7 in 2050, reflecting an increase in direct and indirect energy requirements to produce oil liquids from 15.5% of produced oil liquids currently, to 50% by 2050 (Delannoy et al., 2021).

[3]e.g., LTO hydraulic fracturing, HOB *in-situ* extraction, toxic/radioactive substance accumulation, landscape changes, seismicity (Albishausen, 2020; Marlin-Tackie and Smith, 2020).

The environmental impact assessment of UOs requires careful analysis considering the wide variability between fields and processes, under limited public data availability (Brandt et al., 2018). Life cycle analyses collectively highlight the higher GHG impact of UOs compared to conventional oils (Nduagu and Gates, 2015; Brandt et al., 2018). Exploitation of aging conventional and UO fields combined could translate into 6–26% additional emissions per average barrel produced (Manfroni et al., 2021). Meeting climate targets is generally considered to imply a prompt reduction in global oil consumption (IEA, 2021a), and there is a significant concern that unconventional development may delay clean energy transitions; the overall environmental and social impacts of unconventional resources remain a main argument against their development (Overland, 2015; Marlin-Tackie and Smith, 2020).

The pandemic is thought to have increased public and government receptiveness of pollution and environmental risks (Oxford Energy Forum, 2020), and need for resilience planning in sustainability (Lior, 2020). Higher rates of Covid-19 mortality have been observed in communities exposed to elevated air pollution (Mulvaney et al., 2020). UO indirect socio-economic impacts (Gordon, 2012; Albishausen, 2020) may gain increased importance in a carbon-constrained future and pandemic era, and oil companies may increasingly turn their attention to climate mitigation (Deloitte, 2021; IEA, 2021a). Reducing gas utilization for drilling and refining has been suggested, as well as using renewables for fossil fuel extraction (Manfroni et al., 2021). Limiting flaring and enforcing petcoke disposal (instead of burning) in HOB refining, among others measures, has been estimated to potentially avoid 10–50 cumulative Gt CO_2-eq emissions by 2050 (Brandt et al., 2018). However, production costs could increase in regions with net-zero pledges and reduce producers' competiveness (IEA, 2021b). High carbon tax credits and lowered oil prices following the pandemic have been found to render carbon storage projects in U.S. saline formations more attractive than enhanced oil recovery (Meckel et al., 2021). However, this could consume critical storage capacity from other emitting sectors (Dooley et al., 2009). On the other hand, it has been argued that rapid defossilization could disrupt the fossil energy industry's profitability and constrain climate change mitigation options (Oxford Energy Forum, 2020; Manfroni et al., 2021). Considering fossil revenue losses associated with the pandemic, it is uncertain what emphasis oil companies will place on low-carbon measures and technologies (Kuzemko et al., 2020; Oxford Energy Forum, 2020).

On the demand side, by inducing persistent low-contact (e.g., teleworking) energy expenditure, the pandemic may accelerate electrification and other changes in energy consumption (Oxford Energy Forum, 2020). Remote working is however currently essentially confined to services and dependent on technology often only available in developed economies (IEA, 2021a). Unlike for transport, oil demand for petrochemicals has not been significantly affected by the pandemic, partly owing to the need for medical protective equipment and packaging (IEA, 2021a).

CONCLUSIONS

UO future development, as for the energy sector, is challenging to predict considering the multiplicity and complexity of influencing factors, diversity of views, divergence between short- and long-term goals, and spatial and temporal heterogeneity of the pandemic impacts. While UO has been significantly affected by the Covid-19 pandemic in the short term, limited medium and long-term projections exist, with contrasted findings. A comprehensive analysis of the pandemic impact on UO and broader energy sources considering economic, energy security and environmental aspects is unlikely to be feasible until the pandemic may be considered endemic. Instead, this article highlighted key questions, and potential outcomes and directions to address UO challenges in the pandemic era.

AUTHOR CONTRIBUTIONS

HE initiated the article draft. VE proposed the topic, edited and expanded the article draft.

ACKNOWLEDGMENTS

The authors thank Mr. Timileyin Aworinde, Khalifa University, for assisting in sourcing references.

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