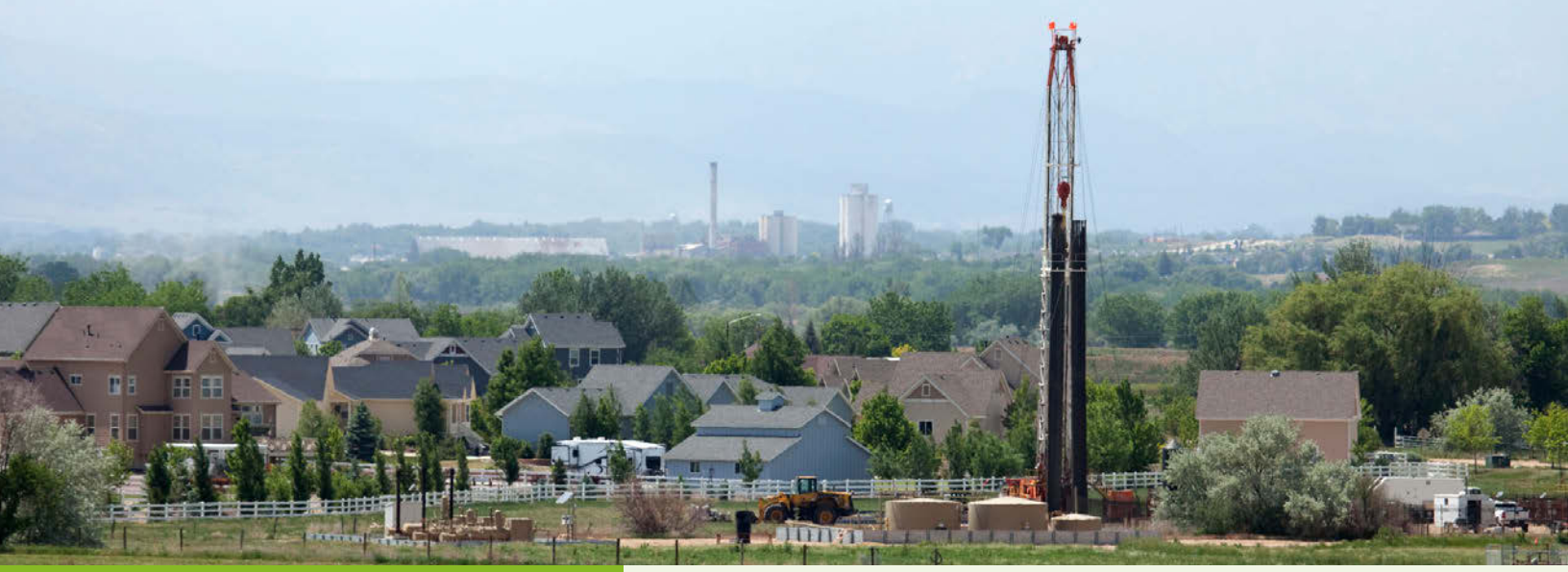

Innovations in Upstream Oil and Gas Operations in Close Proximity to Communities

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Summary of Findings

This research revealed that upstream oil and gas companies are increasingly employing innovative sustainable practices to reduce costs, minimize community impacts, and secure their social license to operate in urban/suburban areas.

Snapshot

Innovative oil and gas (O&G) development practices that mitigate disruption to local populations can pay dividends.

- Upstream oil and gas companies benefit from cost-effective innovations to reduce impacts on the local environment, cultural resources, water supplies, and disruptions to residents, especially in urban/suburban communities.
- Reducing leakage from natural gas infrastructure can mitigate air emission sources, especially methane, from O&G production. O&G companies can implement cost-effective abatement solutions that combine new equipment designed to reduce emissions with improvements in operational practices and regular inspections to detect leaks.
- Innovative water sourcing, water transport, and produced water management and treatment methods can reduce freshwater use and the need for underground injection well disposal. Innovative solutions include using recycled produced water or treated wastewater to fracture wells, using temporary piping to deliver fresh water to the site, and treating produced water from the site through centralized or distributed facilities enabling water reuse.
- Noise-reduction solutions in O&G exploration and production include sound walls, site electrification, use of diesel engines with sound suppression, and identification of truck-traffic-reduction opportunities. Site electrification is an alternative to noisy diesel- or gas-run generators that is increasingly lower cost and can be provided with new and emerging off-grid clean energy technologies or direct grid electrification.
- Reducing truck traffic can be addressed by using temporary piping, rather than trucks, to bring water to well sites and using other piping to dispose of any remaining flowback water after potential recycling is done. These practices can cut the number of trucks to a site in half, substantially reducing local traffic and infrastructure impacts.

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Importance of Innovation in O&G Operations

The O&G industry currently provides the majority of our transportation fuels, chemical and material feedstocks, industrial heat and power, and, increasingly, fuel for electricity generation. Technology advancements in hydraulic fracturing in the past decade have opened up a wider variety of high-potential locations for profitable development, including in areas that have become more densely populated as a result of communities expanding into once-rural areas. Residents near these operations have expressed concerns about these industrial processes and their effects on health, lifestyle, and the environment.

With increased proximity of industrial processes to populated areas, the upstream O&G industry is becoming interested in developing economically recoverable hydrocarbon resources in ways that maximize production while reducing costs and minimizing environmental and health impacts. By operating with a high degree of safety, minimizing community impacts, and collaborating with local communities to address their concerns, the O&G industry can help ensure it retains a social license to operate, not just a legal one. This social license to operate provides companies with a level of acceptance among stakeholders and the public that allows them to do business, which is particularly important in urban/suburban areas.

Figure 1. Electric drill rig.
Photo by Jill Engel-Cox, NREL

In an increasingly cost-competitive industry, some O&G companies are seeking to reduce costs and maintain their ability to operate in suburban areas through innovative sustainable practices. These approaches can provide cost reductions in operations while simultaneously helping meet environmental goals. As an example, electrification of well pads with low-cost, sustainable energy technologies saves on energy costs while simultaneously reducing well site emissions below the regulatory requirement for a costly major source emissions permit.

To obtain a snapshot of the innovative practices and technologies the upstream O&G industry is currently employing or investigating, analysts from the Joint Institute for Strategic Energy Analysis (JISEA) met with small and large companies in the industry. The goal was to objectively analyze what is working and the measurable impacts so that best practices can be broadly shared across the industry. As part of this process, we did a review of one mid-sized company's practices—Extraction Oil & Gas of Denver, Colorado—and will highlight its activities in Colorado to illustrate some of the innovative practices described here.

Overall, our research has revealed evidence of increased innovation in the O&G industry to improve sustainability, driven by stakeholder demands, regulatory requirements, and increasing pressure on the bottom line. Industry innovators and early adopters of sustainable technologies and practices tend to be located where O&G production is expanding into more populated areas, and include mid-sized industry players who have the management vision, financial resources, and operational flexibility to experiment with new ways of doing business. Here we qualitatively outline sustainable innovations being tested or deployed in the upstream O&G industry in the United States as a means to communicate approaches that could be successfully implemented across the industry. We focus on innovations that address five key issues local communities care about—air emissions and odor prevention, water usage and treatment, transportation and traffic reduction, noise reduction, and clean energy development. We also discuss opportunities for engagement and collaboration with local communities for sustainable solutions.

Air Emissions and Odor Prevention

Once air pollutants are emitted, it is difficult to control or remove them; reducing emissions at the source is the most effective strategy to manage emissions and reduce potential air quality burdens. Air pollutants such as nitrogen oxides (NOx) from O&G facility fuel combustion, particulate matter (PM) from road dust, and benzene and methane from equipment leaks can have a range of effects, including health damage to those

Extraction Oil & Gas, which has operations in Broomfield County, Colorado, estimated that it can reduce cumulative volatile organic compound (VOC) emissions by 65% by capping older wells with modern technology even after considering emissions from its new wells.

who breathe the pollutants, reduced visibility (especially over long distances and to scenic vistas), olfactory irritation from odors, and contributions to greenhouse gas emissions, which trap heat. Air emissions are not containable within geographic boundaries, thus, they are of concern from local, state, national, and international perspectives. As complex as controlling emissions from the myriad potential emission points (e.g., leaks in pipes, vents, engine operations, trucks) may seem, it is important to note that in many cases multiple air pollutants are emitted simultaneously. Thus, approaches to reducing emissions from one emission point yield cobenefits of reducing multiple air pollutants. Increased attention and scrutiny on identifying emission points and abatement options have led to the development of cost-effective technologies and strategies that can reduce air pollutant emissions from O&G operations (Columbia Climate Center 2012).

Many innovative solutions have cobenefits beyond reduced air emissions—they can also address traffic, noise, and water management concerns. Considered holistically, there are approaches that can deliver multiple benefits to stakeholders and support the social license to operate for O&G companies. Such solutions include:

- **Tankless on-site water/product management**. Using pipes instead of tank storage and noisy tanker-truck delivery/removal of water and wastewater can reduce air emissions from storage tanks and noise from transport. Storage tanks can be some of the highest- emitting sources on at O&G facilities, especially of VOCs (Lyon et al. 2016).
- **Electric-powered (or dual fuel) equipment.** Replacing diesel-powered drilling and pumping engines with engines connected to the local electric grid or powered by batteries can eliminate air pollutant emissions from diesel sources. If electricity is not available on-site, or if electric engines are not powerful enough, dual-fuel (diesel-natural gas) engines can often be used, which can greatly reduce emissions compared to engines solely fueled by diesel. This substitution will also reduce noise and odors.
- **Capping of older, legacy wells as a condition for new development.** This is one of the more innovative practices, wherein an O&G company seeking new drilling rights agrees to cap older, low-productivity wells, or cap abandoned/legacy wells with more modern technology, as part of the local approval process. With little reduction in local tax revenue, this solution can significantly reduce air emissions from a combined set of older and newer sources. This approach can also free up fully remediated land for other uses, which can be a significant benefit to land-constrained communities in search of additional open space.
- **Equipment upgrades.** Whether replacing existing operating equipment or adding equipment for new operations, upgrades (e.g., replacing continuous pneumatic pumps and controllers with low- or no-bleed equipment), where feasible, can provide the same service with significantly lower emissions (U.S. EPA 2014).
- **Community air monitoring.** To address community concerns about air quality, innovative O&G companies are partnering with local organizations to support air quality monitoring that can establish baseline conditions as well as serve as early warning for potential adverse conditions that lead to increased emissions. This reduces emissions while increasing transparency of data to residents of nearby communities.

Water Usage and Treatment

Advances in horizontal drilling and optimization of the hydraulic fracturing process have facilitated the increase in unconventional O&G development from shale resources. As hydraulic fracturing requires larger quantities of water than conventional development, concerns about water resources have arisen, from both a water quantity and quality perspective.

The issues associated with each phase of the life cycle of water use and management in O&G operations, and appropriate methods of mitigation, vary significantly based on locational characteristics. Risks and mitigation measures are impacted by regional differences in regulations, geography, geology, and hydrology. However, there are common themes and issues in all regions—namely water sourcing, produced water management and treatment, and water transport (the last of these is covered in the Transporation section).

Water Sourcing

The amount of water required for fracturing a single well in the Permian

Basin in 2016 was as much as 42,000 cubic meters, the equivalent of 11 million gallons; in the Bakken region, the required amount was closer to 21,000 cubic meters, or 5.5 million gallons of water (Kondash et al. 2018). Such requirements can have an impact on local water supplies in certain regions. Sustainably sourcing water for use in hydraulic fracturing operations is essential to ensure long-term development opportunities and ensure other nearby water users are not deleteriously affected.

Water can come from many sources, including surface water, groundwater (fresh or brackish), and recycled produced water from the well itself. The main concern about water sourcing for hydraulic fracturing is the potential impact to local and regional drinking water sources. In addition, a decrease in water quantity to streams, lakes, or aquifers can lead to impacts on regional hydrology, wildlife, and downstream municipal water use.

O&G companies pursuing sustainable practices can engage with local stakeholders in internal water planning activities and consider alternative water resources to ensure development activities do not stress local freshwater resources. For example, the City of Dawson Creek in British Columbia and Royal Dutch Shell collaborated on the construction of a wastewater treatment facility for the town. Shell specified the effluent characteristics needed to use this treated wastewater in hydraulic fracturing operations. A 30-mile pipeline was constructed to transport the water out to oil field operations. This provided a service (wastewater treatment) to the local region and reduced Shell's trucking and sourcing costs, while reducing impacts to freshwater resources in the area (Liroff et al. 2014).

Extraction Oil & Gas has partnered with multiple agricultural entities in a single region to lease excess agricultural water resources for use in its operations. The water leases are spread among multiple entities to minimize impacts on any one water user, and the water is transported via existing canals used for agriculture. Extraction Oil & Gas also has helped repair head gates and infrastructure, minimizing losses and maintenance costs for the agricultural entities.

Produced Water Management and Treatment

Produced water management refers to the process of handling wastewater and byproducts of O&G production and traditionally has encompassed the greatest risks for water management (Rozell and Reaven 2012). Produced water can be managed by treatment and reuse in other fracturing operations, treatment at off-site facilities for discharge into surface waters, beneficial reuse in other industries, evaporation in pits, or underground injection in saltwater disposal wells. Treatment options often depend on produced water quality and effluent characteristics after treatment. Treatment to remove inorganic and organic constituents is both energy- and capital-intensive, but the resulting product may be less expensive to store and reuse. Availability of infrastructure for transport, storage, and disposal, along with future development plans and well layout, determines what disposal options are viable during produced water management planning and how much capital is needed to implement a large recycling program. Local geochemistry and the produced water profile dictate what technology is needed to ensure adequate treatment.

Extraction Oil & Gas has implemented pre- and post-operational water sampling near drilling activity to ensure that water sources are not affected and takes extra measures to help ensure contaminants cannot get into or out of well bores.

Companies are working with communities to develop resource management guides and options to support environmental integrity and limit impacts to freshwater resources. For example, as part of development in the Piceance Basin, WPX Energy built out a pipeline and treatment infrastructure for an entire area of development (Lobato 2015). The pipeline infrastructure facility was built to collect produced water, transport it to a centralized treatment facility, treat it to a reuse standard, and then pump it through a separate pipeline to frac pads. WPX has also contracted with other operators in the area to provide treated water for use in fracturing (Lobato 2015). This allows WPX to handle the temporal changes in development and production. Extraction Oil & Gas is building similar infrastructure in Colorado, which will allow it to serve multiple locations within the basin.

Transportation and Traffic Reduction

One issue associated with local community objections to new O&G development relates to increased truck traffic associated with transporting drilling materials, water, sand, and other supplies to the well pad. According to one environmental impact study conducted in New York (NYSDEC 2011), the vast majority of truck traffic associated with "traditional" new wells is used to transport water for

hydraulically fracturing the well or disposing of produced water. The remaining truck traffic is used to transport drilling equipment, hydraulic fracturing equipment, sand, and well completion materials. Potential impacts of increased truck traffic can include increased congestion, damage to roads and bridges, reduced safety, greater noise (as discussed above) and emissions, and increased dust and mud on local roads.

Water-tied trucks have historically accounted for roughly half of all truck traffic at a new site (NYSDEC 2011). Water must be conveyed from its source to the well site and then transported again during the management of fluids produced by the well. Hydraulically fractured wells are often distant from water sources and infrastructure, which requires planning and infrastructure construction to transport source fluid to the site and produced fluids away from the site. Water can be carried to and from the site in trucks and through temporary or permanent pipelines. Operators typically use 400–1,220 truck trips per well for sourcing and disposal (Gilmore, Hupp, and Glathar 2014). The cost of these trips often makes trucking the most expensive part of the total water management cost (API 2011). Trucking also poses risks associated with spills as well as traffic, road, and noise impacts on local communities.

To minimize costs and impacts on local communities, many O&G developers are moving toward water pipeline systems as an alternative to trucking, for both source water and produced water. Pipelines can be used to reduce truck traffic to and from well sites. Pipes must be installed carefully, as poorly installed or inadequately supported pipes can create leak points

Figure 2. Produced water is the majority of truck traffic with new wells.
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over time, but they are generally a significant improvement over trucking. These pipelines can take many forms, such as carbon steel, high-density polyethylene (HDPE), and lay flat piping. For example, in the Marcellus Formation, Anadarko Petroleum developed a pipeline network to deliver freshwater supplies to well sites. Transfers of reused fluid were reduced by treating produced fluid on-site and utilizing the same piping network. They realized a savings of roughly 80,000 trucking trips yearly in the area (CH2M Hill and Energy Water Initiative 2015).

Another solution is codeveloped regional plans with local communities to ensure safe and non-disruptive transport of water during the sourcing, treatment, or disposal phases. For example, prompted by community input and planning with contractors, Noble Energy developed a road use commitment guideline to limit truck traffic to well sites near school starts and during rush hour (Liroff et al. 2014), which is in line with recommendations from the American Petroleum Institute (API) to limit truck traffic frequency at high-impact times of the day (API 2010).

Extraction Oil & Gas introduced the use of sound walls in Colorado and continues to incorporate them into its standard operating procedures based on input from local communities. Combined with quieter equipment, this has resulted in the sound from these sites being largely undectectable at current residential setbacks.

Extraction Oil & Gas is using only temporary piping for its water-sourcing operations, saving 50%–75% on comparable trucking costs and greatly reducing truck traffic at its sites.

For transportation requirements and challenges related to noise and dust, relatively low-tech but effective solutions include containerized sand transport structures that minimize the spread of dust and maximize the amount of sand that can be transported in a single truckload; noise barriers on the well pad that reduce truck noise to local residents; and mud guards that help reduce the spread of mud from tires as trucks leave the drill pad. Furthermore, continuous advances in drilling and fracking processes typically result in faster completions, reduced surface area impacts, and less resource-intensive development.

Noise Reduction and Mitigation

Noise from various stages of development (e.g., drilling, completion, operations) or truck traffic delivering equipment, materials, or fuel is a consequence of oil and gas development. Most of the main sound concerns occur during drilling and completion due to the use of diesel generators to power heavy machinery and the use of pumps during hydraulic fracturing operations. Sound levels during these operations often exceed levels permissible by local authorities, which are typically in the range of 55–65 A-weighted decibels (dBA) for residential and commercial zones (Radtke et al. 2017). OSHA requires personal protective equipment for continuous noise, lasting 8 hours per day, at 90 dBA. This level of noise would exceed the annoyance level for most people in proximity to these operations.

Depending upon the O&G development area's proximity to residential housing, population density, zoning, and existing noise sources, noise could be a contentious issue. If the developer/operator of the O&G site works with neighbors and the community to explain their operations, understand noise-related concerns, and implement various noise-reduction strategies, noise from the site can be reduced significantly. Approaches to noise-reduction include:

- **Sound walls.** Sound walls (commonly 20-ft tall walls covered in acoustic blankets) can noticeably reduce dBA or A-scale sound levels within the O&G development area by approximately 15–22 dBA (Radtke et al. 2017).
- **Use of diesel engines with sound suppression.** Normal diesel fleet sound levels range from approximately 70 dBA to 80 dBA; this sound level can be reduced to 50–60 dBA or less with use of sound-suppression technologies.
- **Site electrification.** Using site electrification rather than power supplied by diesel engines (if economically and operationally feasible) can lower drilling operation sound levels to within acceptable ordinance limits.
- **Identification of truck-traffic-reduction opportunities.** Reducing truck traffic at night near residential areas can prevent nuisance noise.

Additional sound-reduction opportunities may exist with the use of natural-gas-fired energy, renewable energy, and/or energy storage in various stages of O&G development. Noise reductions from O&G operations will be important in retaining or gaining community acceptance as operations spread into new areas.

Clean Energy and Electrification

Production of O&G resources is important to the near-term energy and economic future, but stewardship of environmental resources is also critically important. Energy demand during drilling, completions, and operations varies, but with recent advancements of significantly lower-cost sources of clean electricity, there are new opportunities to use clean energy and/or electrification solutions in O&G operations to improve return on investment and operational efficiency and to address environmental and social issues. New and emerging clean energy technologies, and in some cases, electrification, present opportunities to reduce methane leaks, treat water waste, reduce flared gas, and provide clean power for processing facilities and other O&G operations can be addressed with new and emerging clean energy technologies, and in some cases, electrification.

The broad spectrum of clean energy solutions encompasses natural-gas-powered energy, renewable

Figure 3. "Quiet fleet" (diesel engines with sound supression) for hydraulic fracturing.
Photo by Jill Engel-Cox, NREL

energy, and energy storage. Solutions must be mobile, reliable, modular, and operationally compatible to fit the needs of various O&G operations. Clean energy solutions might not have the energy capacity or duration to meet all the energy needs for every process (e.g., fracturing), but improvements in cost and capabilities are occurring constantly, representing an opportunity for new applications now and in the future. Electrification, including from renewable sources, is one option for helping reduce emissions and noise while lowering operational costs relative to the use of diesel generators for on-site power.

In an era of lower O&G commodity prices and complex state/county environmental regulations, companies of all sizes are trying to make operational improvements within an environmental context. Remote operations have used solar and other renewable energy on a small scale to operate electrified pumps and other small equipment. However, much more opportunity exists than the industry has implemented.

Extraction Oil & Gas has been powering drill operations with overhead 13.8-kV power lines directly from the local electric utility. Diesel engines are on-site in case of grid power outages. Drilling operations that use direct electric grid electrification reduce noise and emissions.

Community Engagement

The recent relationship between the O&G industry and local communities has been strained due to industrial accidents, proposed state and local community hydraulic fracturing restrictions or bans, and heated exchanges at community town hall meetings and in the press. O&G companies have risked losing their social license to operate in urban/suburban communities. Residents argue that O&G producers are not listening to community concerns and cannot ensure 100% risk-free operations, which could affect local property values, water supplies, and cultural resources. O&G producers maintain that that decades of scientific research regarding well development has found little to no impacts to the local environment, and that state and federal regulations are currently stringent enough to reduce operational risks to within acceptable limits.

Disagreements during dialogue occur due to a difference in values. O&G companies believe education and understanding the technology could result in acceptance, whereas local community members may hold views that are not compatible with O&G extraction in any context. For example, some communities in Colorado (e.g., Boulder, Lafayette, Fort Collins) passed local ordinances banning fracking even after attempts at local outreach to educate communities by O&G industry groups. Subsequently, the Colorado Supreme Court struck down the laws because O&G operations are regulated at the state level and not by local entities, which has caused local community members to feel their concerns are being ignored.

Despite such legislative victories, the O&G industry can benefit from directly

Concerns	Responses by Leading Innovative Companies
O&G companies are not listening to community members	Prioritize working within communities, listening to and responding to concerns in city council and engagement events, and implementing best practices/suggestions for reduction of concerns, as applicable by site
Operations are impacting local routines	Change operational schedules (switch to night work for some activities) and prioritize work during the summer near school zones; O&G companies plan heavy trucking operations to avoid school starts and ends (Extraction, CH2M Hill and Energy Water Initiative 2015)
Operations are disrupting residents	Implement sound barriers around sites during drilling and completion activities to reduce sound impacts; use electric completion fleets, which results in large sound reductions
Operations have negative impacts on local cultural resources	Site drilling pads away from cultural resources important to the local community as identified through up-front engagement; remove legacy items (e.g., old wells, pipes, tanks); offset land disruptions by donating restored land to local communities for open spaces
Operations have negative impacts on local water supplies	Implement voluntary water monitoring measures to ensure local water resources are unimpaired
Operations have long-term negative impacts	Use pipelines—not trucks—in a fully closed-loop process for moving oil, natural gas, and water to reduce traffic and emissions, eliminate the need for permanent storage tanks, and reduce the likelihood of spills in the area

addressing community concerns. Innovative technologies and practices being tested and implemented have potential help O&G companies improve their operations economically, socially, and environmentally. Included in this section is a chart summarizing the specific concerns from community members with examples of how some O&G companies are responding.

Independent science experts should help provide bias-free information to local communities and the O&G industry, and can facilitate exchanges between communities and O&G companies to work toward technical solutions that result in community acceptance. JISEA works collaboratively with the O&G industry to analyze and improve the sustainability of operations through solutions ranging from measures to reduce methane emissions to electrification of operations using clean power. We invite industry and community partners to collaborate with us to improve understanding of how sustainable innovations can improve operations while protecting and enhancing nearby communities and their environment.

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