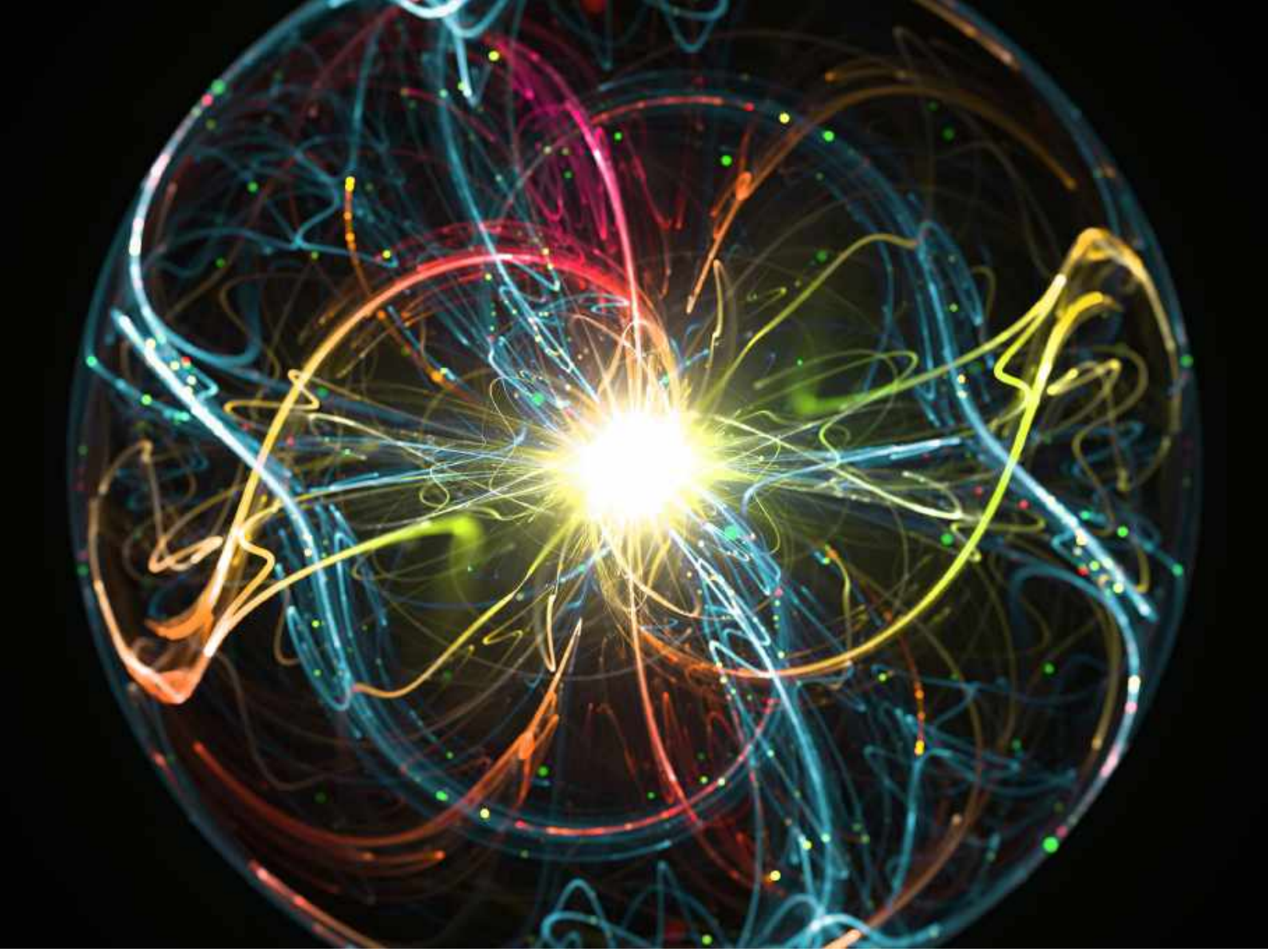


Navigating the energy transition

How energy companies are shaping their future

Arthur D. Little's "Energy & Convergence" Report

September 2020

Arthur D Little

Arthur D Little

Energy & Utilities

Editorial Board

About Arthur D. Little

www.adlittle.com

Arthur D. Little has been at the forefront of innovation since 1886. We are an acknowledged thought leader in linking strategy, innovation and transformation in technology-intensive and converging industries. We navigate our clients through changing business ecosystems to uncover new growth opportunities. We enable our clients to build innovation capabilities and transform their organizations.

Our consultants have strong practical industry experience combined with excellent knowledge of key trends and dynamics. ADL is present in the most important business centers around the world. We are proud to serve most of the Fortune 1000 companies, in addition to other leading firms and public sector organizations.

About ADL's Energy & Utilities Practice

www.adlittle.com/energy

The Energy & Utilities practice helps Arthur D. Little's clients create value through the energy transition.

The Practice works side-by-side with its clients along the energy value chain and counts more than 300 practitioners globally organized in Competency Centers and Studios addressing issues ranging from new business models, digital transformation, innovation and sustainability.

About ADL's Energy & Convergence Report

www.adlittle.com/energyandconvergencereport

The Energy & Convergence Report is Arthur D. Little's publication dedicated to shedding light on the key issues that affect our clients as they navigate and shape their organizations for the energy transition.

The Report is a collection of practical and forward-looking viewpoints based on our client experience, authored by our Energy & Utilities experts, and reviewed by our Editorial Board.

Contacts

If you would like more information or to arrange an informal discussion on the issues raised here and how they affect your business, please contact:

Austria
Bela Virag
virag.bela@adlittle.com

Belgium
Kurt Baes
baes.kurt@adlittle.com

China
Yusuke Harada
harada.yusuke@adlittle.com

Czech Republic
Lukas Vylupek
vylupek.lukas@adlittle.com

France
Vincent Bamberger
bamberger.vincent@adlittle.com

Germany
Michael Kruse
kruse.michael@adlittle.com

India
Barnik Maitra
maitra.barnik@adlittle.com

Italy
Saverio Caldani
caldani.saverio@adlittle.com

Japan
Yusuke Harada
harada.yusuke@adlittle.com

Korea
Chulseung Son
son.chulseung@adlittle.com

Latin America
Daniel Monzon
monzon.daniel@adlittle.com

Lebanon
Albert Kostanian
kostanian.albert@adlittle.com

Middle East
Adnan Merhaba
merhaba.adnan@adlittle.com

The Netherlands
Martijn Eikelenboom
eikelenboom.martijn@adlittle.com

Norway
Lars Thurmann-Moe
thurmann-moe.lars@adlittle.com

Poland
Piotr Baranowski
baranowski.piotr@adlittle.com

Russian Federation
Pavel Luzbuh
luzbuh.pavel@adlittle.com

Singapore
Yuma Ito
ito.yuma@adlittle.com

Spain
Juan Gonzàlez
gonzalez.juan@adlittle.com

Sweden
Lars Thurmann-Moe
thurmann-moe.lars@adlittle.com

Switzerland
Michael Kruse
kruse.michael@adlittle.com

Turkey
Coskun Baban
baban.coskun@adlittle.com

UK
Nick White
white.nick@adlittle.com

USA
Rodolfo Guzman
guzman.rodolfo@adlittle.com

Foreword

Michael Kruse
Partner and Global Head of the Energy
& Utilities Practice

Dear readers,

The preparation for this edition of our periodic Energy Journal started just before the Covid-19 pandemic hit global society six months ago. We have since then realized that energy companies are showing particular resilience to address the mega-trends of the industry and continuing their journey to transform their business models and value chain architectures.

Covid-19 might have slowed down the pace of this transition in parts of the value chain to some extent, but overall the need to innovate is still intact and even essential. In fact, we have experienced how agile companies navigated through the crisis by re-defining their ways of working and by establishing new ways of interacting with their customers and suppliers. Clearly, Covid-19 is not the driver for the energy transition but it has provided energy companies with opportunities to rapidly transform parts of their value creation ecosystem.

We are certain that all players within the energy and utilities sector such as national and international oil companies, power producers, transmission and distribution system operators as well as energy wholesalers and retailers must build on the current industry dynamics.

We believe that the current edition of Arthur D. Little's flagship report is a relevant and valuable body of knowledge and expertise to reflect on the key business issues that are critical to the energy transition. These include discussions about the need for hydrogen and e-fuels to decarbonize societies, the end of the traditional gasoline retail model, demystification of electric charging, but also controversial discussions about delivering the nuclear promise and the energy consumer of the future.

Arthur D. Little helps clients navigate through their journey. We have always been at the forefront of innovation and we are now more than ever at the vanguard of delivering practical and forward-looking solutions that uncover new growth opportunities in the changing energy ecosystem.

Michael Kruse
Managing Partner, Global Leader Energy & Utilities Practice

Arthur D Little

Content

Shift in business models

Getting ready for the energy consumer of the future 07
Potential pathways and frameworks to help business leaders develop new essential capabilities
Authors: Aurelien Guichard, Paola Carvajal, Carl Bate, Greg Smith, with contributions from Michael Kruse, Matthias von Bechtolsheim, Felix Keck

18 Weathering the perfect storm
COVID-19 and the future of the oil & gas industry
Authors: Rodolfo Guzman, Daniel Monzon, Aurelien Guichard

What's next for TSOs? 26
Leading the way in the energy transition
Authors: Kurt Baes, Florence Carlot, Maxime Dehaene

31 Energy retailers: Facing the toughest transition in the energy sector
Energy retailers in Europe need to leverage an increasingly open energy ecosystem to differentiate and stay competitive
Authors: Kurt Baes, Andrea Romboli, Florence Carlot, Loic Vervaeke

On utility-mobility convergence

The forecourt of the future 42
With a disruptive lifestyle and technological changes ahead, the fuel retail business will need to create a new customer experience on the forecourt
Authors: Daniel Monzon, Catalina De Stefano, Carlo Stella

46 Electric mobility impact on downstream oil business
Threat or opportunity?
Authors: Daniel Monzon, Carlo Stella, Mariano Aztiria

Demystifying the charging challenge 55
A driver for convergence and new business opportunities
Authors: Alexander Krug, Andreas Schulze, Kai Karolin Hüppe, Johannes Herr

Digital and operations excellence

69 Upscaling digital pilots in Oil & Gas
How are oil and gas companies adopting digital in their operations and how can they shift from pilots to full-scale implementation?
Authors: Adnan Merhaba, Amer Hage Chahine, and Theresa Karam

Nuclear lean 73
Combining safety culture and operational excellence
Authors: Tommaso Sacco, Michael Kruse, Bernd Schreiber, Kai-Oliver Zander

Looking ahead at energy offerings

78 Flexibility services: catch me if you can!
Why and how utilities should seize the opportunity before others do
Authors: Kurt Baes, Florence Carlot and Maxime Dehaene

The evolution of the street lighting market 83
What is its role in smart city development?
Authors: Saverio Caldani, Irene Macchiarelli, Andrea Romboli, Vincenzo Ippolito

98 The future of hydrogen and e-fuels
Will it bethe new oil?
Authors: Christian Adolph, Dr. Matthias von Bechtolsheim, Roman Mathyssek, Dr. Klaus Schmitz, Dietrich von Trotha

Getting ready for the energy consumer of the future

Aurelien Guichard, Paola Carvajal, Carl Bate, Greg Smith, with contributions from Michael Kruse, Matthias von Bechtolsheim, Felix Keck

The energy sector is undergoing radical transformation as formerly passive consumers take control over their energy consumption and procurement. Based on the five stages of this transformation, we explain how it impacts the energy value chain and outline the capabilities that traditional providers must embrace if they are to meet the needs of the energy consumer of the future.

Today's consumers expect convenience as a matter of course – and want greater control over everything they buy and do. This trend is now spreading from sectors such as retail and transport to energy, with customers moving from being passive consumers to playing a more active role in managing their energy consumption and procurement. And as digital technology, electric vehicles and distributed power generation all increase, these trends will accelerate and expand in scale. This will inevitably lead to a reorganized energy value chain and drive the emergence of new business models. What is the impact on incumbent energy providers in the oil, natural gas, power, and utility industries? Who will win the race to attract the energy consumer of the future? This article aims to map potential pathways and provides a framework to help business leaders develop the new essential capabilities.

The evolving energy consumer

Within retail and transportation, consumers have already embraced the platform-based Amazon and Uber models, increasing their control and ensuring they get what they really need, when they need it, without the time and friction of going through intermediaries.

The same trends are moving into the energy world, where customers will increasingly adopt and adapt digital systems. These digital tools will enable customers to better meet their own needs, which will lead to new business models that will allow them to personalize their energy requirements. Based on our research and analysis, we see in Figure 1 a path that

takes energy consumers globally through five main phases. Depending on local energy market development, some consumers in advanced countries are already ahead in this evolution.

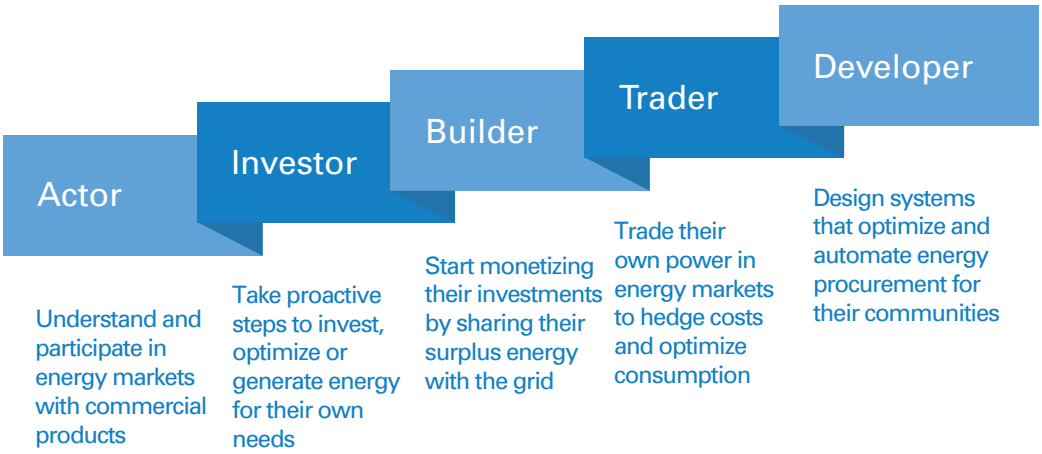


Figure 1: Evolution of the energy consumer

Actors: Initially, consumers take advantage of energy efficiency and demand response programs in order to reduce their costs and carbon footprints. In certain US and European markets, they are aware of the unbundling of power generation and energy retail, which means they switch energy providers according to their preferences. They invest in smart devices that connect to their smart homes and cars to learn and understand their behaviors. They transact individually through digital channels with their energy providers, although they have limited ability to influence products and rates.

Investors: With increasingly energy-efficient and environmentally friendly behaviors, consumers put the focus on services that allow them to optimize their energy consumption. They install methods of distributed energy resources (such as photovoltaic solar panels on their rooftops and battery/energy storage on their side of the electric meter) and produce energy for self-consumption and for the grid. This is a fundamental change for utilities that means they have to rethink, and reverse, their unidirectional contracting strategies with their customers. As the gap in the total cost of mobility

between electric and gasoline-powered vehicles narrows, consumers also assess which provides their best option for transport. This means traditional fuel retailers and suppliers need to transform their customer service as they start to compete with utilities. In advanced gas markets, consumers assess electric versus gas as an energy choice.

Builders: Consumers optimize their dependency on energy products. From a power perspective, customers make their spare supply available to their neighbors and transact with each other when needed, which offsets and reduces any reliance on grid services. This challenges the business models of incumbent utilities, which have traditionally invested in centralized, capital-intensive assets funded by utility customers. In terms of mobility, customers prefer not to spend time driving to, and waiting at, the gas station anymore, and this therefore threatens the relevance of this traditional value chain.

Traders: With the rise of battery systems and electric vehicles, consumers have turned into virtual traders. They start balancing – essentially hedging – their energy consumption with their own production. They tailor and schedule their activities to commercially advantageous times of the day and night. Even commercial and industrial consumers trade energy on digital platforms to the extent that they need to keep their core business operations running. Their energy consumption and generation systems are nimble and respond to surge pricing events, which further disintermediates incumbent power and fuel providers.

Developers: When these behaviors spread to entire communities, consumers work together to design energy systems that optimize resilience and cost for their own communities. In doing so, they build total systems that cover heating and cooling, building automation and smart neighborhoods, telecoms and broadband, and transportation and mobility. Utilities and oil and gas companies provide reliability and safety through their existing infrastructure, but they are no longer the sole providers of value-added services to consumers.

Preparing for the energy future

Building on the convergence of new technologies and business models, the energy consumers of the future are connected, commercial, and autonomous, virtually making (and transacting) power within an "Amazon of energy". Consequently, they will play the leading role in the future world of energy – and incumbent players need to react now to be ready.

In order to adapt to how consumers use and produce energy, we see three ways in which businesses can respond, each of which will have radical impact on the energy value chain. These are shown in Figure 2. Equally, they will need to develop new capabilities to power this transformation, which we describe in the next section.

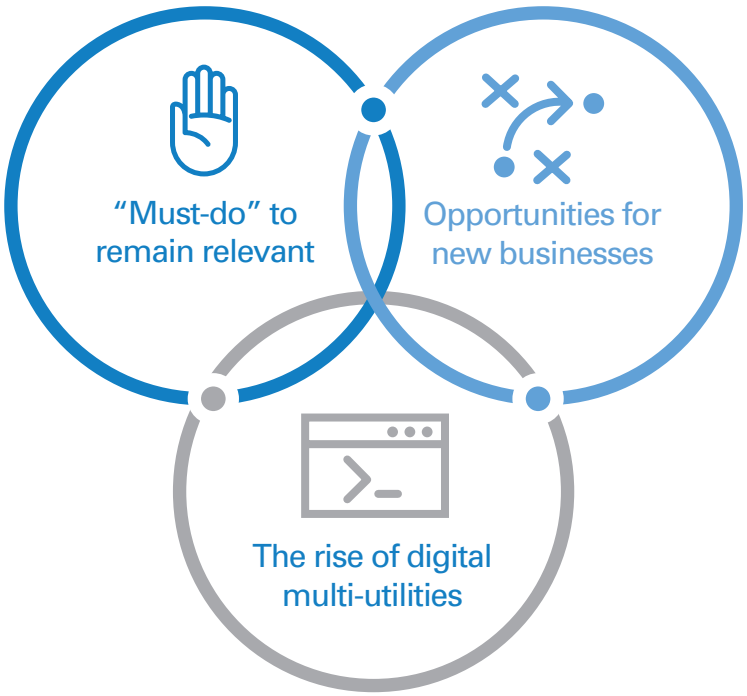


Figure 2: Business responses to evolving consumer behaviors

"Must-do" to remain relevant: Incumbent energy companies need to embrace the consumer-driven model and develop **new digital businesses** that offer convenience and new services around the delivery of their existing products to customers. They need to move from "sign in to your account" websites and "locate your nearest gas station" apps to interactive and personalized customer portals. Examples range from E.ON's Energy Manager in Europe to Duke Energy's Power Manager in the US and Diamond Energy's bill reduction offer with Reposit Power in Australia. They need to focus on personalizing their products, including rethinking consumer-to-utility contracts, based on extensive investment in the customer experience and greater consumer understanding. Input from consumers further drives this personalization, which results in a new demand dynamic for energy generation and consumption.

Opportunities for new businesses: Companies may also venture out of their current business models and invest in developing **new transformative products** that respond to consumer desires for greater energy efficiency. Companies can incrementally extend their scope and reach to provide services further up and down the energy value chain. Some may engage in M&A transactions (for example, Swiss utility BKW acquiring 40-plus service businesses in engineering and building technology), while others will grow organically (for example, electric utility Southern Company offering fiber-optic solutions, as well as Shell venturing into mobile fueling services with TapUp). As a result, they augment their customer value propositions by pushing new products to their markets.

The rise of digital multi-utilities: New, disruptive intermediaries may become the ultimate digital multi-utilities, aggregating consumer needs, social preferences, energy availability, partner ecosystems, and delivery service optionality to fuel the consumer's entire personalized energy lifestyle. As seen in other industries, such as media and travel, these businesses ingest and process massive amounts of data across various information sources and make consumer

predictions based on artificial intelligence. In addition, the network platform effect allows consumers to monetize their assets across electricity, heating/cooling, and mobility fuels. By being independent from incumbents, this **"energy-as-a-service"** response provides the most personalization, convenience, and value-add, which we believe will offset the higher acquisition costs of implementing consumer digital technologies. This is also the most disruptive response for traditional energy providers, as it reduces the relevance of the historic energy value chain and forces oil and gas companies and electric utilities to collaborate (or compete) with each other.

There are already some good examples of how competitors in the industry are responding, as seen below.

How competitors are responding to the energy consumer of the future

Traditional energy companies

Large energy companies are already taking significant steps to shift their focus, as previously discussed in "Shaping the oil company of the future" in Prism issue 1, 2019. Many existing utilities struggle with lack of **direct engagement with local consumers**, although some are aiming to bridge this gap. For example, EDF Luminus offers flexibility, energy assets (solar panels, battery packs, electric vehicle chargers), and services beyond traditional gas and electricity. Overall, major oil and gas operators invested $3–4 billion in low-carbon energy solutions in 2018 – slightly over 1 percent of their capital budgets. Given that 2018 global investments in distributed energy and clean technology overall totaled more than $300 billion, oil and gas companies are not the only players.

Consumer products companies

On the consumer products side, smart home vendors are helping customers control the temperature in their houses, reduce their energy usage, and make significant savings on their bills. There is a fierce battle raging for control of the smart home between market leader Google Nest, followed by Ecobee, Honeywell, Samsung, and Amazon's Alexa platform. All are investing massively in order to own the new smart home, managed via apps and voice control. This is just the beginning – companies such as Ecobee are leveraging artificial intelligence to **listen, learn, and respond to consumer behavior and market pricing**, automatically adjusting energy consumption based on real-time weather and electricity rates and acting as virtual batteries for energy. In the mobility space, companies are starting to penetrate the consumer energy market with offerings that directly affect energy consumption – for example, Volkswagen's Elli, a webshop for green power supply and charging solutions for electric vehicles.

New energy companies

New entrants are seizing specific opportunities, based on in-depth knowledge of generation and consumption patterns. Companies such as LO3 Energy and GridPlus in the US, Power Ledger and GreenSync in Australia/the UK, and Vandebron and Powerpeers in the Netherlands are beginning to reshape how energy is distributed across the grid by allowing **consumers to transact energy** with one another. In Germany, digital platforms for B2B power and gas procurement are emerging. Players such as enPortal, e.less, enermarket, and Verivox for retail, as well as tender365 and enmacc for wholesale, support fully digitalized, end-to-end buying and selling energy capabilities. While they connect buyers with utilities today, they will become pure P2P trading businesses in the next five years. On the gasoline side, start-ups such as filld.com and startyoshi.com began by providing delivery to individual cars, and are now expanding to bundle maintenance services and offer discounts on retail gasoline.

The spark for action

As energy consumers favor and adopt offerings from integrated, digital multi-utility and energy-as-a-service business models, the global energy value chain is finding itself on the cusp of being fundamentally disrupted. Traditional gas and electric utilities, as well as liquid-fuel providers, certainly have a valuable set of competitive advantages across customers, products, and logistics, but these are being challenged by new entrants.

We believe the businesses that are able to listen to their customers' behaviors across multiple platforms and rapidly offer them tailored energy solutions will be successful in the long term. Incumbent energy providers therefore need to take steps to build new communication channels, foundational product capabilities, and the advanced analytics necessary to remain the suppliers of choice. We show five key capabilities that are fundamental to achieving the necessary transformation in Figure 3. Many of these are new to established companies' mind-sets:

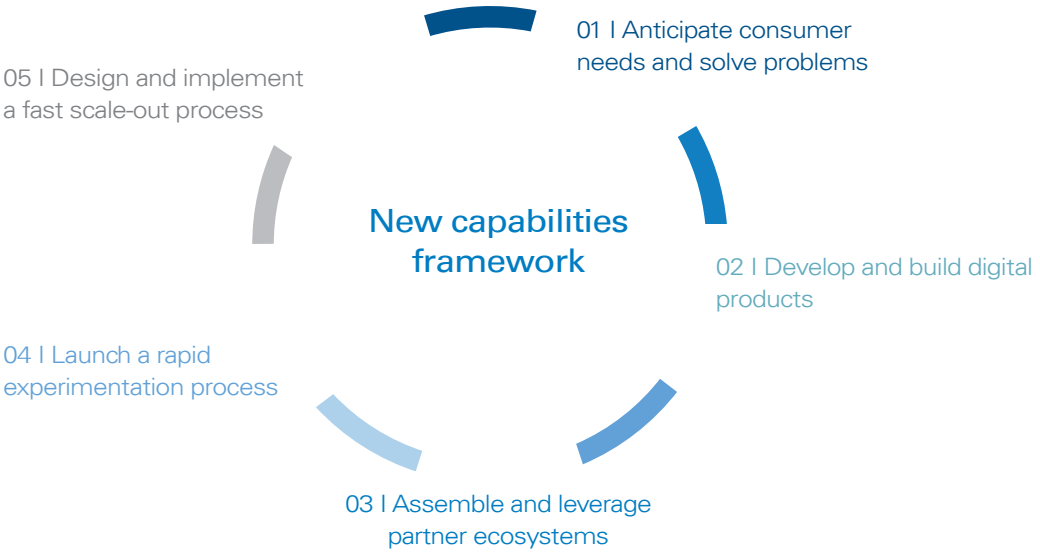


Figure 3: New capabilities framework

01 | Anticipate consumer needs and solve problems: Based on specific local market conditions, energy companies need to leverage issue-centric problem solving to avoid implementing today's "best" practices, and instead craft their consumers' "next" practices. Previously, energy providers followed best practices to solve relatively predictable consumer problems that were flagged to them. In the more fluid future market, they will need to move to convergence-driven problem solving. They need to anticipate new, future needs and actually identify solutions to problems before consumers realize there is an issue. This can only be achieved by adopting consumer anticipation-based design thinking and aggressively expanding direct consumer engagement, so they can understand and incorporate consumer insight into design and innovation processes.

02 | Develop and build digital products: Players need to invest boldly in the resources and skills which allow their teams to develop and fine-tune their digital technologies and offerings. The objective should be to align energy product offerings with energy customer priorities as they evolve. Technologies that capture energy customer behaviors and patterns spanning multiple information channels will be the most relevant investments for energy providers to personalize their solutions. The capabilities to strategically design, engineer, and architect digital businesses will be key to unlocking digital opportunities.

03 | Assemble and leverage ecosystems of partners: Business leaders need to actively develop and maintain networks of partners that bring unique and complementary capabilities to their organizations. Energy-as-a-service means that customers play the central role in the transformation of the industry value chain. Traditional power utilities, oil and gas producers and retailers, technology developers, and start-ups, among others, should be able to leverage synergies to satisfy energy customer expectations. Beyond traditional supplier partnerships, companies also need to manage technology ventures that can be monitored, evaluated, and scaled up

once de-risked, as well as corporate-start-up collaboration platforms such as accelerators and incubators, to bring in new, breakthrough thinking.

04 | Launch a rapid experimentation process: To compete in the fast-paced digital environment, leaders need to implement comprehensive processes that let their organizations iterate to tangibly measure – and learn – from testing and experimenting with new products and business models before engaging in pilots and commercialization at scale. Managing technology pilots requires rigor and discipline – and a broad view of the business. So the company needs a structure to enable teams to ideate, a process to guide the incubation stage, and a system to link the learnings back to the overall business.

05 | Design and implement a fast scale-out process: Energy companies have been traditionally strong at managing projects, infrastructure, and commodities through multi-year and decade-long cycles. For the future energy consumer, they will need to transform their established value propositions and at a much faster pace. Their capabilities to scale out solutions to their markets will become critical. The key strength and competitive advantage will therefore rely on a nimble, yet effective, commercialization process and go-to-market approach, which will require an agile mind-set for change and collaboration across multiple corporate functions.

Equipped with this capabilities framework, business leaders can start setting the new direction for their companies in line with the requirements of future energy consumers, and therefore take leading roles in the future ecosystem and value chain.

Insight for the executive

The energy consumer of the future will adopt and adapt digital systems that will enable them to control their energy footprints, which will lead to new business models of energy-as-a-service. Energy companies will face multiple disruptions to their businesses, and need to act in new and different ways to remain ahead:

- Develop new digital businesses that offer convenience and personalized options for delivery of their existing energy products to customers.
- Launch new energy products to respond to particular customer desires, strengthening their offerings as broader energy service providers.
- Transform their businesses towards digital multi-utilities that can offer integrated and optimized total energy solutions to their customers.

The energy transition is also opening the door to new players such as smart device manufacturers and network developers, which are focusing on interacting with customers and understanding their needs to provide personalized solutions. These new ecosystems represent not only challenges, but also opportunities, for incumbent energy companies. Ultimately, incumbents need to shift their core engineering capabilities from infrastructure assets to software platforms and digital assets. Such a transformation requires significant effort to develop new capabilities:

- Anticipating consumer needs and solving problems
- Developing and building digital products
- Assembling and leveraging ecosystems of partners
- Launching a rapid experimentation process
- Designing and implementing a fast scale-out process

Weathering the perfect storm

COVID-19 and the future of the oil & gas industry

Executive summary

The oil price war has combined with the COVID-19 crisis to create a perfect storm for the petroleum industry, with oversupply and low prices expected to last for years. Arthur D. Little believes the crisis will have a major impact on the oil industry: decarbonization trends will accelerate and alter the industry's approach to climate change. Immediate and lasting impacts on the industry are likely to drive a structural transformation, leaving fewer players after the crisis. There is a chance that the market will get "back to normal" sooner than expected – however, it is more likely that the oil industry will continue to lose its appeal to investors.

1. Volatility of the oil & gas industry over the past decade

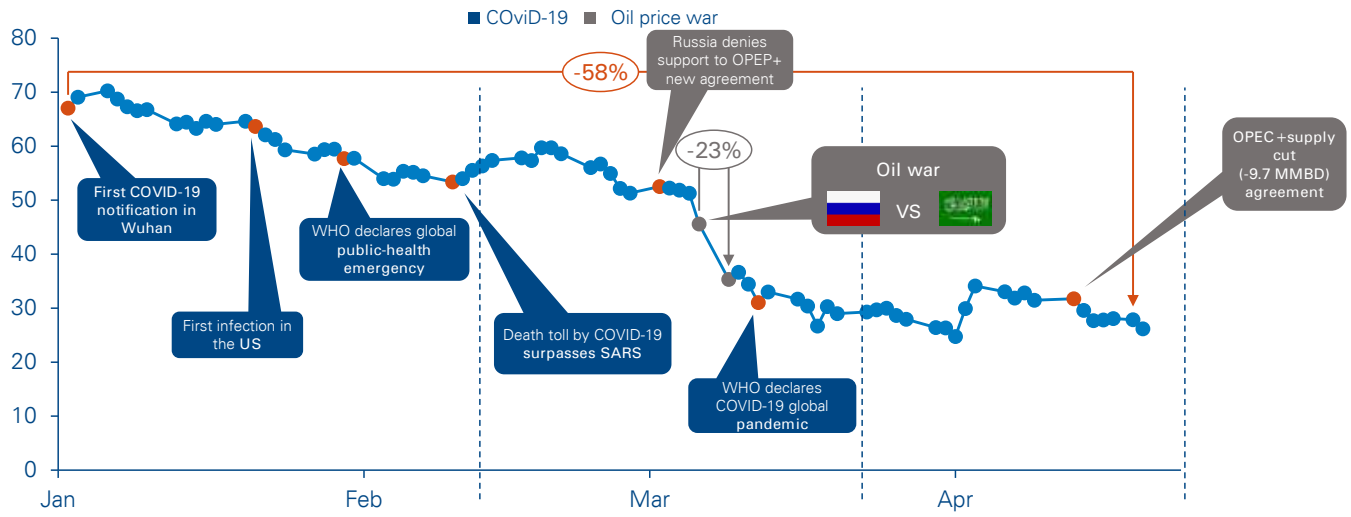
The global lockdown in response to the COVID-19 pandemic has pushed an already-volatile oil & gas market into crisis. On the one hand, the oil & gas industry is already in a major period of transition, with mounting pressure for society to be less reliant on oil and gas in the face of climate change, which has led some companies to diversify into the renewable energy sector. On the other hand, competition for market share within the industry remains fierce, as evidenced by the recent price war between OPEC and Russia.

However, the current situation created by COVID-19 is unprecedented, with the pandemic causing a sudden and dramatic reduction in global energy demand – one which is likely to continue for many months to come, if not longer. This has severely exacerbated the existing problem of oversupply and low prices.

Prior to the COVID-19 lockdown:

- Over the past few years, and following a period of high crude-oil prices, the US has become the world's top oil producer, a consequence of new extraction technologies, with particular emphasis on shale hydrocarbons.
- After the first signs of demand drop in Asia and before occidental lockdown, Saudi Arabia/OPEC entered a price war with Russia, taking advantage of its own relatively low production costs and high levels of production capacity and reserves to ramp up supply. This pushed crude prices down to levels under $35/bbl.
- For the US and other players with much higher production costs, including those reliant on unconventional methods of oil extraction (such as shale and oil-sands), it is already difficult to operate profitably at this price level.
- As well as challenging the US market share, this poses an existential threat to some independent oil and gas companies, with progressive cancellation of projects and operational shutdown of high-cost oil production.
- The global refining sector is also transforming, with the addition of large-scale, high-complexity facilities in the Middle East and Asia displacing smaller, low-conversion plants, which are no longer able to cover their cash operating costs and annual CAPEX requirements.

Brent Spot price dollars per barrel



Source: Arthur D. Little, EIA, Forbes, World Health Organization, press releases, El País, oil price

- Natural gas prices have also dropped significantly, due to a decrease in demand and excess LNG capacity, with major CAPEX cuts and deferral of multi-billion-dollar projects previously announced.
- In parallel, agreed climate change policies demand that the world reduce its CO_2 emissions – notably from hydrocarbon-based sources – and embrace greener energy sources, as well as accelerate a sharp transition to a much lower-carbon economy by 2030, at the latest.
- As such, the industry anticipates that peak oil demand will occur within 15 years' time, with some major players in oil and gas already diversifying into renewable energy sectors.

The COVID-19 effect:

- The global lockdown necessitated by the COVID-19 pandemic has exacerbated these trends, deepening the crisis of oversupply, exaggerating the drop in crude-oil prices and forcing further shutdowns.
- Demand forecasts change every week, but with a drop of over 30 percent in flights and light-vehicle transit to less than half in many regions, average global reductions of more than 10MBD could be expected for 2020.
- The economic slowdown caused by the measures taken to combat COVID-19 is likely to trigger a global recession, which, at the very least, will have a negative impact on oil and gas demand for many months to come, if not longer.
- Similarly, although an agreement has recently been reached between OPEC, Russia, and others, to address the immediate oversupply by cutting oil production over the next few months, crude prices are set to remain below $40bbl for the foreseeable future, due to surplus and pre-existing inventories.
- In the short term, this is likely to drive a number of small and highly leveraged companies to the wall, as they will be unable to operate at this price point because their margins will be eroded – this will also be the case for companies focused solely on high-cost production assets.
- Despite having entered into this price war, the national budgets of the OPEC countries and Russia will be severely impacted by low oil prices, particularly if they continue for more than a few months.
- Depending on the nature of the post-COVID-19 recovery period, peak oil demand may occur sooner than originally predicted.

2. Possible scenarios for the oil & gas industry in a post COVID-19 world

With the oil & gas industry currently locked into a negative cycle of oversupply and price drops, the economic downturn created by the COVID-19 crisis will deal a death blow to a significant number of companies. There will be an economic recovery at some point in the future, but it is highly unlikely that the overall global economy will return to pre-COVID-19 "business as usual", at least not soon. Instead, the oil & gas sector will be forced to confront a substantial reduction in demand due to both lower economic activity and increased pressures to embrace greener, lower-fossil-fuel energy sources.

It seems clear that the impact of COVID-19 will push the oil & gas industry even harder towards an earlier structural transformation, which will result in fewer and more agile players. Even in the best-possible scenario, the petroleum industry will continue to lose appeal to investors and shareholders, as has progressively been the case for the past 10 years.

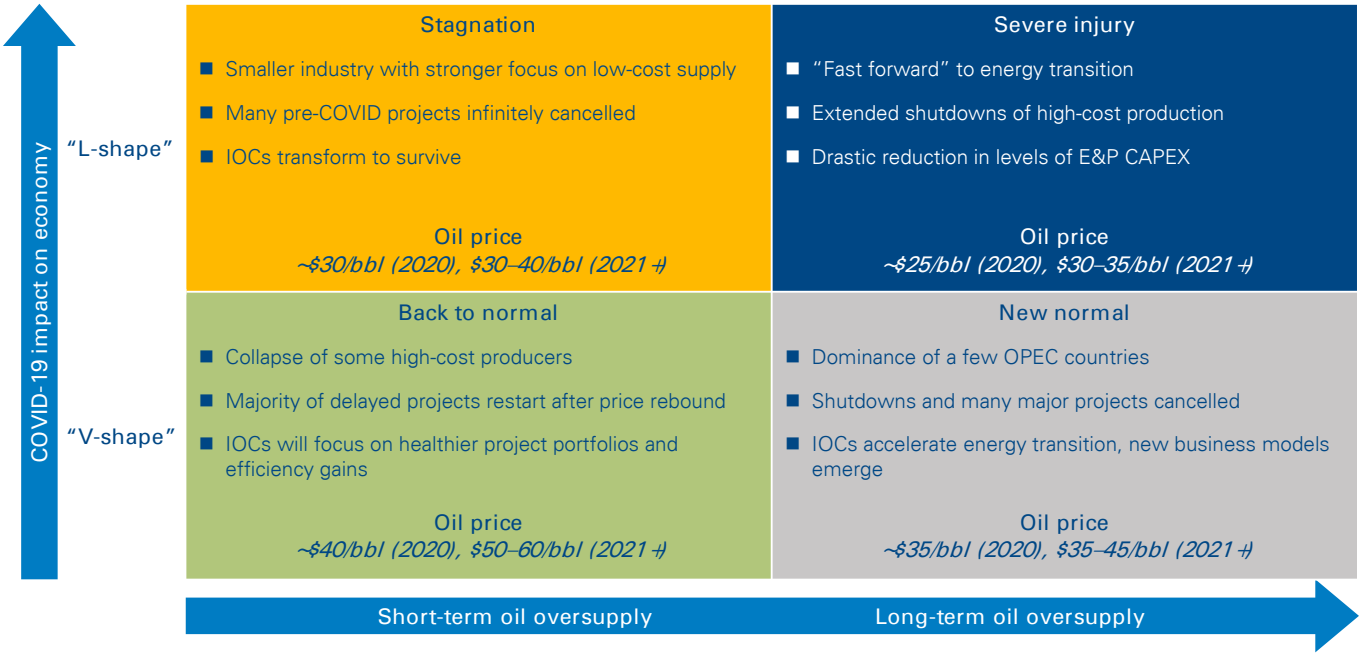
The likelihood of the scenario "Back to Normal" is relatively low, since it strongly depends on a "V-shape" bounce in the economy, as well as the main oil producers deciding – and being able – to cut production significantly to reduce oversupply.

The scenario of "Stagnation" seems more likely, in which economy and demand impact is "L-shaped", and supply adjusts over time to support prices in the $30–40Bbl range.

If both the economy and demand bounce after a few months, OPEC and other main producing countries will probably lose the sense of urgency to support prices by cutting supply. In this case the industry will face a "New Normal" scenario, with OPEC once again assuming pre-eminent leadership within the market and oil prices remaining relatively low.

The worst scenario for the industry is "Severe Injury", with both slow economic/demand recovery and persistence of oversupply. We believe this is less probable than the "Stagnation" and "New Normal" scenarios since a lasting demand drop would motivate OPEC and other producers to adjust supply to support prices after a period of time. The level of "injury" to both individual players and the petroleum industry as a whole will depend on whether OPEC commits to supporting prices or leaves the market to make the economic adjustment to balance supply and demand.

Petroleum industry scenarios – Economic impact versus persistence of oversupply



Source: Arthur D. Little, Brent quotes for oil price

International oil company (IOC) reserves have an average production life of just 10 years, and with exploration for new reserves significantly reduced, their share of production (and market power) will progressively shrink. OPEC has over 50 years' worth of oil reserves, and combined with generally low production costs, will ultimately displace much IOC market access. However, OPEC countries cannot afford to keep oil prices this low indefinitely: petroleum-based economies will need prices to rise in order to support national budgets and spending programs, or they will risk political instability.

Looking more closely at how the business model of each industry sector will be affected, we predict the following:

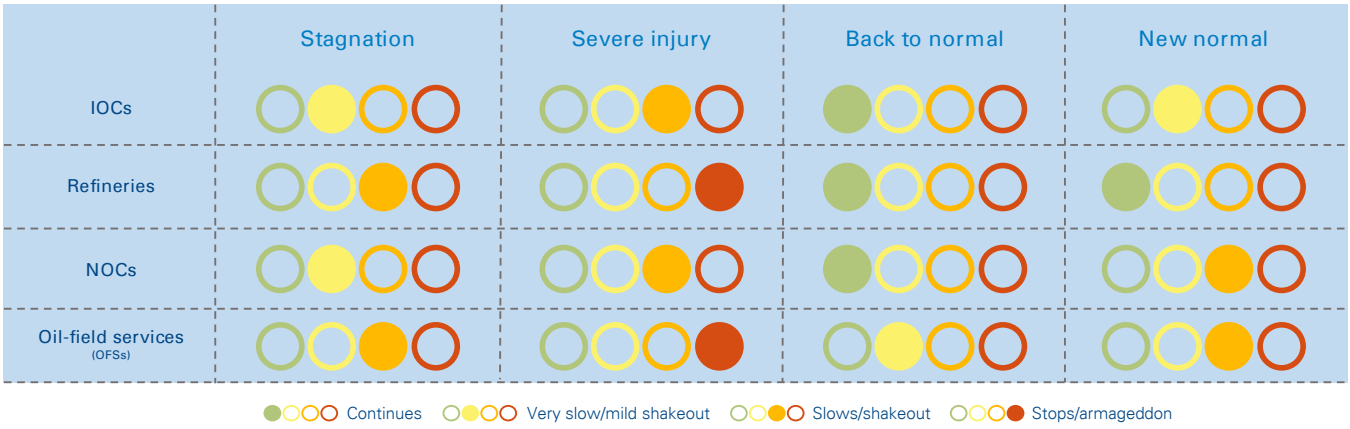
- **International oil companies** will find it increasingly difficult to grow organically, although there may be more M&A opportunities as smaller players struggle to compete. It is also likely that certain high-cost and stranded assets will be written off. However, strategies designed to decarbonize the asset portfolio, and those that favor strengthening renewables and natural gas positions will be much more appealing to stakeholders .
- **National oil companies (NOCs)** with large, low-cost reserves will push to monetize their value, perhaps over a shorter time period than previously planned – however, NOCs with higher domestic cost structures are likely to shrink. Due to reduced oil and gas revenue, lower national budgets in most of these countries will intensify debate about reinvestment priorities versus pressing social needs, and some governments may use this crisis to spur support for or compel NOCs to adopt energy transition programs.
- **Refining** players will face low margins for years to come due to structural overcapacity and heterogenous demand evolution by region. In light of this, conversion and quality capital projects will need to be reviewed, while some small-scale assets will not be able to cover their annual maintenance investment needs.
- **Oil-field services** players face low utilization of assets and staff because of project cancellations and production shutdowns.

Although a significant number of players in the oil & gas sector may lose market share, there are nevertheless opportunities for companies willing and able to transform their business models. In the short term, this may involve consolidation via acquisition of high-quality assets from failed or collapsing companies. However, with traditional oil margins now fatally eroded for many companies, other energy investments should become more attractive.

Oil and gas are not only increasingly unprofitable to find, produce and industrialize, but also finite resources. Climate change is driving a move to a greener, cleaner-energy economy, with government policies driving increased renewables penetration across the globe. As renewable energy use has become more widespread, infrastructure costs have fallen accordingly, encouraged by financial incentives connected with meeting "green targets". Oil & gas projects now have lower returns and higher levels of uncertainty than ever before; in contrast, renewables continue to have lower technical risks, and also now have potentially lower commercial risk and relatively higher rates of return.

However, there is a possible flipside to this new energy landscape. While the climate for renewables has never been more favorable, fossil fuels may nevertheless remain more competitive in the short term if oil prices stay low. Although both businesses and consumers are keen to use greener energy sources, they may be swayed to stick with oil and/or gas if it becomes (and remains) significantly cheaper. Similarly, governments may prioritize economy recovery over green subsidies and continue to invest in oil- and gas-fuelled power while there is a plentiful, competitively priced supply. The US and Canada will certainly support their oil & gas sectors and try to prevent their collapse.

Impact by player under each scenario



Source: Arthur D. Little

3. Accelerating decarbonization trends after COVID-19

The COVID-19 lockdown has thrown the issues facing the oil & gas industry into stark relief. However, while the battle over supply, price and market share could be viewed as a crisis of its own making, the industry ultimately understands that, whatever scenario turns out to be correct, peak demand for oil is going to happen soon – due to COVID-19, perhaps sooner than expected. Companies that have already been far-sighted enough to invest in low-cost assets and the energy transition are in the best position to capitalize on this situation, in which a prolonged run on the price of crude looks set to make the traditional oil & gas model much riskier and less commercially attractive than ever before for most players. And with oil & gas much less of a sure bet, investors will be increasingly persuaded to put their money into the renewables sector instead.

Arthur D. Little believes a post-COVID-19 world will see the oil & gas industry accelerate its transition to a cleaner and more diversified portfolio of energy sources, products and service offerings, promoting higher energy efficiency and decarbonization. COVID-19 has created a perfect storm that, along with the ongoing and urgent need to reduce CO2 emissions in order to fight climate change, should persuade the industry to embrace transformation in faster and smarter ways. For many players, future survival and success depend not only on greater focus on renewable energy, but also turning the industry into a modern, energy-efficient business sector matched by a zeal for intelligent automation and digitalization of working processes.

Potential ecosystem for future oil companies

Source: Arthur D. Little

Conclusions

The COVID-19 lockdown requires an immediate response from all segments of the industry

All oil and gas industry segments – from field operations and services to refining, transport and distribution – have been affected by the COVID-19 slowdown. As already noted, some companies will not survive because their negative margins will inevitably lead to operational shutdowns and financial distress.

In the short term, companies need to focus on two core areas to gain the best-possible chance to weather the COVID-19 storm:

- **Asset and CAPEX portfolio review and control**
  Companies need to critically review their existing capital budgets and asset portfolios, and where possible, cut capital expenditure. This will mean cancellation of planned quality/conversion upgrades, construction of new facilities, and proposed greenfield projects. Costly exploration projects will also need to be reined in, particularly high-risk ones, despite the inevitable knock-on effect as reserves become depleted. As certain asset classes become less profitable, there will also be a need for restructuring: low-cost, short-payback assets are to be prioritized, and high-cost, long-payback assets must be suspended or cancelled.
- **Ongoing efficiency optimization**
  This crisis should bring ongoing efficiency initiatives into even sharper focus, with all elements of the supply chain scrutinized and reassessed in pursuit of potential savings. Now is the time to renegotiate contracts with suppliers and partners or cancel them altogether. Similarly, companies should critically examine all aspects of their operations, with manpower kept at minimum levels for the foreseeable future. However, with such processes having been ongoing for most companies since the financial crash of 2008 and the price crash of 2014, significant cost-efficiencies and savings may not be available.

In the medium term, portfolio management and ongoing efficiency optimization are necessary but not sufficient on their own: only **true transformation of their business models** will ensure long-term viability for most industry players.

For almost every player, it is necessary to rethink objectives, geographic and business scope, and route to market. For companies focused solely on high-cost production assets, such as shale, tar sands and deep water, this may be a major challenge, and a significant proportion of these companies are likely to progressively shrink, collapse or be acquired. For companies already beginning to diversify their energy sources, now is the time to push harder in this direction and invest further in energy efficiency, decarbonization and renewables as such projects become more attractive because of lower technical, commercial and financial risks. There is also likely to be considerable consolidation across the sector as industry portfolios designed for one price point struggle to adjust to life in a new, much harsher environment.

Authors
Rodolfo Guzman, Daniel Monzon, Aurelien Guichard

www.adl.com/WeatheringTheStorm

What's next for TSOs?

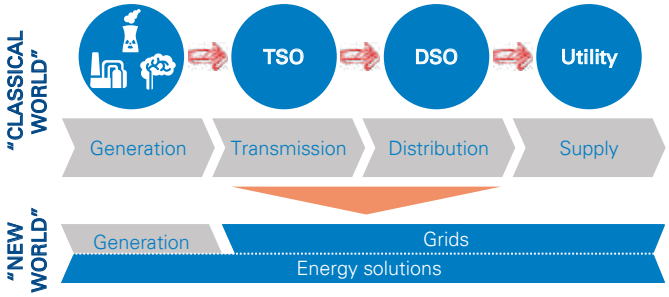
Leading the way in the energy transition

Within the energy ecosystem, the transition towards a more sustainable future mostly materializes through rapid increases in renewable energy sources, distributed generation and energy storage at large. The increasing share of intermittent generation sources is redefining the rules of the game – roles and accountability within the energy value chain are turned upside down. While the traditional role of the electricity Transmission System Operator (TSO) is more relevant than ever, fundamentally reshaping the future is equally high on the agenda, as it is triggered by game-changing factors such as new stakeholders, higher stress on the energy grid, digitalization, intermittence and flexibility. Here we share our learnings from recent Arthur D. Little projects.

New rules of the game within the energy ecosystem

Renewables and the increasing use of distributed generation sources are stretching the traditional energy grids, which were built to accommodate large central generation units and one-way distribution system operator (DSO) networks. Current prosumer reality has inverted the system, new actors have emerged (e.g., aggregators), geographies are increasingly interconnected, and all ecosystem stakeholders are rethinking their strategies. Specifically, a whole range of "energy solutions" are emerging along the value chain, forcing energy industry participants to rethink their traditional business models. In addition, central generation is transforming, with offshore wind and PV parks that mandate new "transmission highways", as well as skyrocketing asset investments in energy grid backbones.

Value chain evolution



Source: Arthur D. Little

As a result, the traditional "linear" grid structure is evolving towards a "meshed" structure, and both TSOs and DSOs need to deal with new flexibility requirements and constraints. The need for a transformation at network level is reinforced by adoption of new technologies and use cases such as (large-scale and residential) batteries and electric vehicles (smart charging, vehicle-to-grid), as well as emergence of new electricity generation models such as virtual power plants (VPPs) and demand-side response (DSR). On the one hand, this challenges traditional network operator models, but on the other, it offers opportunities to existing and new players.

TSOs: Facilitate ongoing change, or lead the way?

Although the electricity system will continue to require a central transmission backbone network (central generation, whether it is conventional or renewable, is forecasted to remain predominant in the generation mix for the foreseeable future), the rise of intermittent, decentralized generation and micro-grids could lead to a decrease in reliance on transmission networks. For grid owners, this creates the risk of stranded assets and related regulated revenues. Multiple responses exist. Rather than mere defensive moves, TSOs have the opportunity to step out of their position in the value chain by leveraging innovative technologies and new use cases. There are multiple examples of how TSOs can transcend their "traditional regulated role":

- International expansion: e.g., Red Eléctrica invests in transmission assets in Latin America
- Entry into energy system services: e.g., Elia Group provides technical consultancy services through its independent EGI subsidiary, supporting other grid operators in a range of energy system services
- Deployment of new technologies in test-and-pilot set-up: e.g., Terna and RTE invest in batteries in a range of applications for congested and imbalanced grid assets
- National Grid has developed a blockchain energy-trading platform and pushes EV fast-charging networks
- TenneT tests linking decentralized home storage solutions via blockchain to stabilize the grid

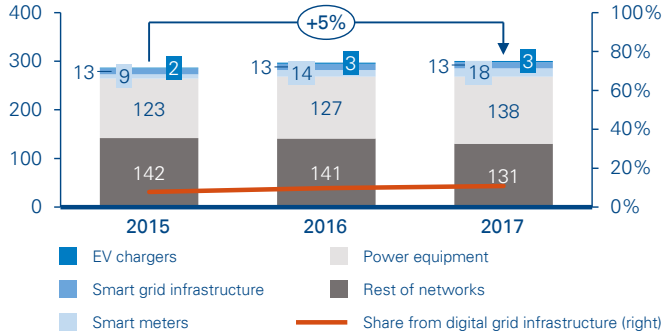
More opportunities will arise for TSOs willing to supplement the "classical" world with the emerging "transition" world, in which new priorities exist along four main axes: system operation, asset management, ecosystem facilitation and diversification (see below figure). This overview of opportunities stems from our implication in supporting TSOs in the definition and the development of their ambitions.

System operation

With the classical electricity transmission grid still essential for optimal functioning of electricity markets, "keeping the lights on" remains the core activity of TSOs. Additional activities do become equally important, such as optimizing market design and rules to cope with the increasing need for flexibility. Recent grid-balancing mechanisms that rely on traditional generation assets (such as DSR) and new assets (such as batteries), as well as the increasingly decentralized generation and consumption patterns, are the basis of transformation of electricity grids from linear "one-way streets" towards meshed "two-way streets". To ensure proper balancing of the network, some TSOs have developed novel, real-time platforms to provide the required flexibility. These platforms optimally define the cost and incentive associated with each transaction, taking into account real-time supply and demand.

Keeping the bidirectional meshed grid constantly balanced also requires TSOs and DSOs to increase their degree of collaboration day to day. The prosumer energy flow stimulates a shift in roles and responsibilities, which forces DSOs to perform system operation-related tasks which were previously exclusive to TSOs (e.g., congestion management, enhanced voltage management). In this context, increased collaboration would allow DSOs to benefit from the knowledge TSOs have developed over the years.

Share of spending on electricity network equipment by type
World, 2015–2017, USD bn

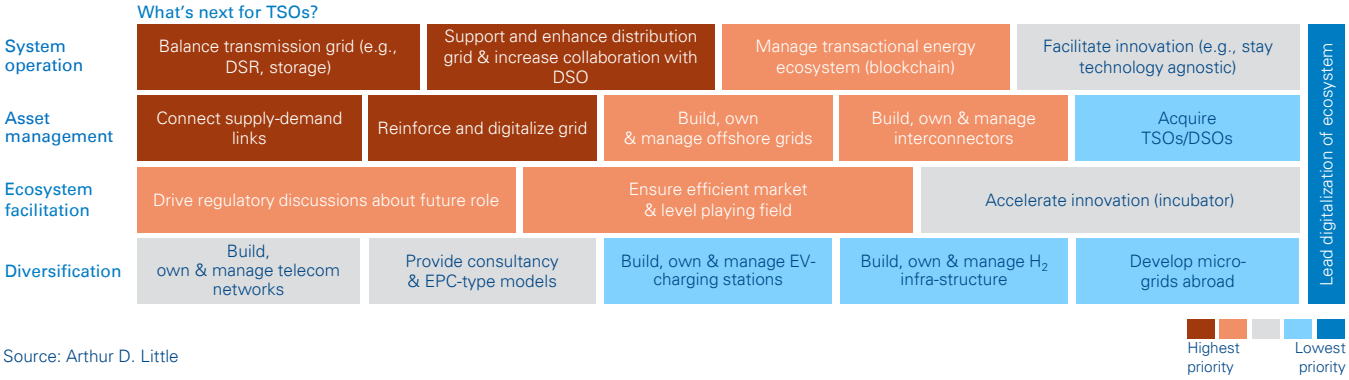


Source: EIA, Arthur D. Little analysis

In addition, the increasing complexity within the future transactional energy ecosystem advocates for central management of core grid-balancing functions. In this regard, TSOs could play an important role in managing the data hub required to keep track of all transactions (e.g., through the use of blockchain technology). However, the evolution from a couple of hundred injection points towards a couple of million will make fully central calculation and communication very challenging. As a result, a set-up in which a number of tasks are managed centrally (e.g., ensuring security of supply), while other tasks are solved on the spot by local teams, is to be expected.

Given their central position, TSOs will play an important role in shaping the technological characteristics of tomorrow's electricity system. Although they might not all directly invest in research & development, their decisions in terms of platforms, requirements towards (new) players, etc., will drive technological development and deployment. Belgian TSO Elia, for example, is applying this in practice: by designing technology-agnostic ancillary services, it is enabling new technologies such as battery systems to partake in the energy market more actively,

TSO role by priority



Source: Arthur D. Little

thereby stimulating a market boost for new energy services at large.

Asset management

Multiple European TSOs have announced/launched ambitious CAPEX plans that aim to further develop and reinforce their grids. These CAPEX plans are mainly driven by changing generation and consumption patterns (nuclear phase-out, increase in renewables, increase in distributed generation, etc.), as well as the increasing average age of assets on many transmission grids. In addition, the emergence of new technologies, combined with rising (regulatory) pressure on efficiency, increasingly requires TSOs to digitalize asset management and maintenance to ensure efficient grid management and operation. Indeed, while spending on standard equipment such as cables, transformers, switchgear and substations accounts for approximately 90 percent of total network investment, the share of smart grid technologies continues to rise (see above figure). As one of RTE's executives puts it: "We increasingly rely on silicon, not only on copper and steel".

Case study:

TenneT is investing heavily in Germany to connect offshore wind farms in the North Sea

Since 2006, TenneT has been responsible for developing and operating grid connections to offshore wind farms in its German area. TenneT will play a crucial role in connecting the offshore wind farms that the German government is planning to build (total capacity of 6.5 GW).

In addition, TenneT has developed a vision for a hub-and-spoke concept for large-scale wind energy on the North Sea. The company suggests building an artificial island to centralize electricity from multiple wind farms and using HVDC cables to transport electricity to the mainland. The cables would also interconnect North Sea countries.

Although it is not unusual for TSOs to deal with offshore grids, they often follow different regulatory frameworks. As such, offshore grid management offers a greenfield diversification opportunity.

Aside from this, development of offshore renewable generation assets leads to increasing grid development and reinforcement requirements, and also generates new opportunities. TSOs can capture new revenues from owning and operating offshore transmission assets outside of their home countries, thanks to a regulatory context which is often less restrictive than that for the mainland. In this context, multiple TSOs are developing the required capabilities to design and build offshore grids (see German case study). However, this also creates opportunities for new actors to enter the transmission value chain: companies such as Diamond Transmission Corporation, part of the Mitsubishi group, now own transmission assets, which they acquired through offshore wind developments in Western Europe.

Another CAPEX-intensive area for TSOs is the increasing international coupling of transmission grids. Numerous European projects of common interest involve building electric interconnections between the transmission grids of adjacent countries. Given that interconnectors have become part of the transmission networks of multiple TSOs, they are often built and operated in close collaboration. TSOs, having built one or multiple "local" interconnectors, can leverage the specific capabilities they have developed to build, and potentially own and manage, interconnectors in other countries.

TSOs willing to further leverage their asset management capabilities can also acquire grid companies (both TSOs and DSOs) abroad. This will allow them to optimally leverage the grid development, system operation and asset management capabilities they have developed in their respective markets – such as Elia's acquisition of 50Hertz. These types of initiatives will allow them to maximize shareholder value and diversify their portfolios of activities from a geographical and regulatory point of view.

Ecosystem facilitation

The energy ecosystem as a whole is undergoing fast-paced evolution. On the one hand, this questions the traditional role of each player in the value chain, but on the other hand, it creates opportunities for new/emerging roles. If traditional players are

Case study:

Initiatives to foster and support innovation within the energy ecosystem

Elia has launched a number of initiatives to stimulate innovation within the context of the energy transition:

- Elia stimulates innovation by investing in start-ups, such as energy software company Enervalis. The start-up's software enables "passive customers" to become an active part of the energy ecosystem. More specifically, Enervalis designs software to enable smart microgrids, smart buildings, smart EV charging and smart settlement.
- Elia has launched its second open innovation challenge for start-ups. The aim of the second edition is to improve forecasting of electricity production and consumption, while the first edition of the challenge focused on innovative solutions to increase public acceptance of the electricity grid.

not vigilant, these new roles may be fulfilled by new types of players (e.g., aggregators, new – offshore – transmission entrants). These new players might gradually conquer a share of the value in the market, decreasing the value left for traditional players.

In this context, it is of utmost importance for TSOs to reflect about the role they want to have in the future energy ecosystem and drive regulation in the right direction. TSOs are in the perfect position to facilitate and steer the ecosystem. As such, they should ensure the market as a whole is efficient and considered to be a level playing field by all potential players. In addition, TSOs could drive and accelerate innovation within the electricity ecosystem. They can achieve this by acting as incubators for new technologies (see Belgian case study), and ultimately by taking a leading role in the enhancement of the entire ecosystem.

Diversification

To maximize shareholder value, TSOs can pursue diversification opportunities outside of their core activities. On the one hand, they can leverage their specific skills and know-how by building, owning and managing telecom/utility networks, providing consultancy and EPC-type services or contributing to developing and building micro-grids in remote areas. On the other hand, they can leverage their long(er) investment horizons and technical knowhow to invest in infrastructure potentially adjacent to their transmission networks, such as electric vehicle (fast) charging stations and H2 infrastructure.

Key takeaways

While traditional grid management will remain necessary, the energy transition will challenge the historical allocation of roles in the electricity ecosystem and create new opportunities. We have seen from recent projects that these opportunities can be exploited by either existing players or new ones, especially considering new evolutions such as the emergence of micro-grids. Decentralized generation, as well as new, digitally-enabled use cases (DSR, V2G, P2P networks, etc.), will contribute to blurring the distinction between the roles of TSOs and DSOs. It will stimulate grid operators to increase their collaboration and partner with new players (e.g., aggregators) to achieve win-win situations.

In this context, TSOs will need to clearly define which role they want to play and stimulate regulatory clarity. While TSOs will never be service companies (as they are not allowed to own or operate generation units or provide flexibility services), they must make use of their current position in the value chain to evolve towards central facilitators, driving the development of electricity ecosystems across multiple facets and ensuring the system is capable of supporting all kinds of new players and use cases.

Authors

Kurt Baes, Florence Carlot, Maxime Dehaene

www.adl.com/FutureOfTSO

Energy retailers: Facing the toughest transition in the energy sector

Energy retailers in Europe need to leverage an increasingly open energy ecosystem to differentiate and stay competitive

Executive summary

Power and gas selling is commoditizing at lightning speed in an open market in which competition is hyper-agile and creative with retail add-on services. As a result, increasing customer switching rates and thinner margins directly impact traditional incumbent retailers. A key question is if and how these companies can shift their business models to break free from traditional positions to capitalize on the opportunities created by an ever-growing energy ecosystem.

In this paper, we offer a view of the challenges energy retailers face, and which strategic moves they need to consider to reinvent themselves and stay relevant in the future. Guided by their sense of purpose, retailers need to consider where in the ecosystem they want to focus and with which partners, as well as how to transform their organizations to anticipate innovation and create services that adapt to changing consumer behaviors.

1. Challenges faced by energy retailers in Europe

Energy retail profitability is at its lowest in years, while customer-churn levels and new-entrant numbers are at their highest

Almost two decades after the liberalization of energy markets in the developed world, the cards have been thoroughly reshuffled, with many new cards added and nearly all rules redefined. Traditional utilities have seen the entry of new players across the energy value chain. Further fueled by the megatrends of decentralization, digitization and decarbonization, their businesses have been disrupted significantly, which has resulted in many challenges. In this section we outline the main challenges and underlying drivers. In the next section, we explore ways forward for a better future.

1. A whole lot of new competitors

Non-energy leaders throughout various industries have entered the power and gas sector, leveraging their existing capabilities, customer relationships and other value-chain positions (such as hardware and services) to enter energy retail. Among them, we find those that are new to the energy sector, such as car manufacturers, GAFA ("Google, Apple, Facebook, Amazon") and telecom operators. In addition, others are broadening their scope of activities towards energy retail, building on positions in the extended energy value chain (such as equipment firms and service providers). Finally, a range of start-ups are also entering, some from the energy sector and others from outside (see Figure 1). Many see the energy sector as an opportunity to develop new revenue streams and expand the number of touchpoints with their existing customer bases.

Figure 1: Cross-industry players competing in the energy retailer business

		Telecom	Automotive	Oil & gas	GAFA	Energy equipment and solutions	Start-ups
		Leverage existing customer commercial/billing relationship	Increase customer touchpoints for EVs	Hedge and diversify against peak oil demand, environmental regulations	Leverage advanced technology know-how (data, cloud) to address customers' needs	Leverage their energy assets to broaden their scope of activities	Equipped with advanced technology, have the advantage to tap into energy market
Generation	Asset investment/ management	Commission of RE generation assets (Telstra)	Solar energy park building	Solar farms building/ installation, onshore wind park operation		Investment in large-scale batteries (NEC)	
	Virtual power plant			Flexibility management from generation assets and load (Limejump)		Acquisition of stakes in aggregator of generation assets (yuso)	Flexibility management from generation assets and load (next)
Electricity/gas supply			Green electricity supply (Elli)			Energy supply (Eneco)	Energy supply
Add-on services	Bundle service heating/internet/tv/...	First provider of mobile solutions and, recently, energy plans (amaysim)		Supplier of gas, electricity, broadband, boiler care (Shell Energy)			
	E-mobility	Operation of charging sockets for EV-charging infrastructure	EV-charging infrastructure (Nissan)	Electric vehicle-charging infrastructure (Chevron)			
	Smart home	Smart energy meters, thermostats, lighting systems (Comcast, Deutsche Telekom)			Sensors, locks, lights, cameras, thermostats (Apple)		
	Energy efficiency				Analyzing demand from smart home (amazon)		Pairing artificial intelligence with energy storage to automate energy cost savings (stem)
	Demand response (load management)				Adjust energy consumption in real time (Nest)		
	Energy storage systems (ESS)		Procurement/distribution of 2nd-life batteries, battery modules & consultation for energy-storage systems	Electric battery (Saft, Tesla)		Installation of energy-storage solutions (Hanwha)	Store clean solar power during the day to power homes at night (Wattstorage)

Source: Arthur D. Little analysis

As a consequence, we have assisted with a wave of consolidation among different types of players.

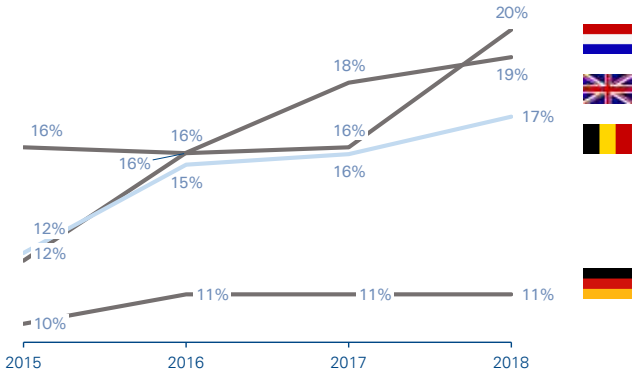
Many retailers have acquired aggregators: Centrica of REstore, Shell of Limejump, Engie of majority stakes in KiWi Power, Enel of EnerNOC, etc. This trend is also true for electric mobility charging-station providers: Engie acquired EV-Box, Shell bought NewMotion, and EDF group acquired Pivot Power.

In a very dominated market, incumbents typically are the ones acquiring the new players, as was the case in the Netherlands with the first wave of new entrants in 2004. Vattenfall bought Nuon in 2009 and Delta in 2019, and Eneco bought new entrant Oxxio in 2011. However, nowadays, we note a reverse trend. The perfect example is Ovo Energy, which was established in the UK in 2009. Ten years later it acquired SSE, one of the UK's top six energy providers (known as the "Big Six"). Ovo Energy's share of the electricity market increased from 0 percent in 2013 to 5 percent by the end of 2018, while the Big Six, in contrast, all lost market share (from 100 percent in 2010 to 73 percent in 2018). Other beneficiaries of this decreasing trend are Octopus Energy and Bulb, both of which entered the market in 2015.

2. Sky-high switching rates

In some mature EU markets, external[1] household switching rates for electricity reach 10–20 percent (see Figure 2) , although in some markets, such as Germany, switching rates remain stable. On the commercial and industrial (C&I) front, switching is intensifying as well. In Italy, for example, the switching rate for non-residential electricity customers increased from 12 to 17 percent between 2010 and 2018. In the UK, the number of renegotiated contracts increased over a three-year period (2015–2018), from 70 to 73 percent on the electricity side and 70 to 76 percent on the gas side. Not only are energy consumers becoming more active in terms of switching, but it is often the first step to becoming more active in managing their energy consumption and procurement. (For a more extensive overview of future energy consumers' behavior, see "Getting ready for the energy consumer of the future" in ADL's second Prism issue of 2019.)

Figure 2: Household electricity switching rates (2015–2018)



Source: Arthur D. Little analysis

3. Rigidity of the incumbent

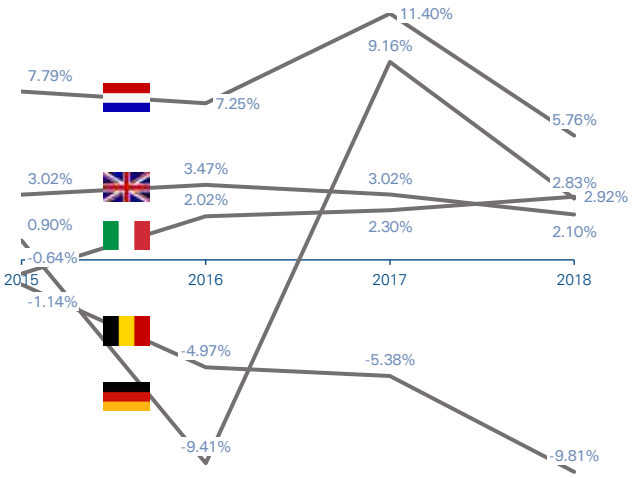
Incumbent players are structurally less agile due to their heritage. They typically rely on older infrastructures and systems, and use more staff to run operations. In contrast, successful new entrants will benefit from the latest technologies in that they are more agile and rely on nimble, optimized back-end systems for client operations and energy procurement during their start-up phases. Once they climb the growth curve, a higher number of clients can be efficiently handled with less full-time equivalents (FTEs) than for traditional players. Not only does the effectiveness of operations impact their costs, but the lack of smooth client processes is a trigger for customers to churn, looking for better experiences.

4. Low profitability

New competitors, higher switching rates and lack of internal agility result in low profitability for incumbent retailers. The lowest levels of EBIT margins recorded in years are shown in Figure 3. Retailers typically make money on loyal customers (referred to as "sleeper" contracts) once they have earned back the acquisition costs related to that customer, which often runs to €150+ (in the form of cash-backs, gifts, commissions, etc.). Therefore, higher switching rates mean suppliers are not just facing higher retention costs or failing to capitalize on their investments into those customers.

5. Changing and evolving regulation

Figure 3: Average EBIT margins of incumbent retailers (2015–2018)[2]



Source: Arthur D. Little analysis

Besides these main challenges, and like they do for other activities in the energy value chain, regulators are making up (and changing) their minds on a wide range of topics – most of the time in favor of customers and often with potentially high impact for retailers. As an illustration, capacity markets are halted or reinstated, markets deregulated, climate goals sharpened, etc. Another illustration with consequences for 2020 is the updated EU Directive 2019/944, which obliges suppliers of EU member states to offer at least one dynamic pricing tariff by December. Aside from affecting their operations, those changes could have a negative impact on the end-customer bill, which would include added environmental charges from suppliers being passed through to customers.

Although the last decade has been challenging for energy retailers, we believe these times can be equally exciting, as industries are converging and energy consumers are pulling attention towards them. Both trends can represent a new pool of value for retailers that will be agile enough to grab the related opportunities. In this rapidly evolving environment, what can energy retailers do to thrive?

2. Four strategic focus areas to succeed

Helping energy retailers to reinvent themselves through four fundamental questions

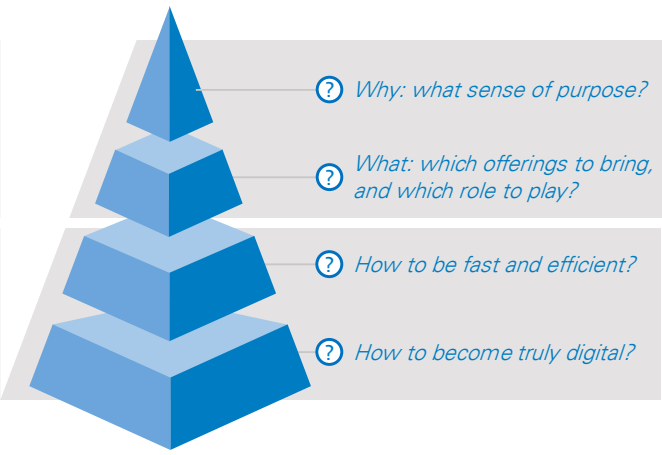
Today's energy-retailer CXOs are confronted by challenges that cover the increasingly broad space in which their businesses exist, with much shorter times to act and react. (See ADL article: The CEO – Lost in space and time?) In this new "extended space, accelerated time" environment, CXOs must answer four strategic questions with the objective of building sustainable competitive advantage and outperforming competitors in tomorrow's environment. Answering those questions will help CXOs navigate the challenging times. It will guide them in their search for differentiating value propositions that fit with customer expectations, while helping them reflect on their operating models to improve their outcomes.

1. What is our sense of purpose? WHY is our company in this world?

Given the more volatile, uncertain and complex business environment, companies need a resilient sense of purpose that will be the key to bringing value to their clients and staff, as well as society at large.

In the past, energy-retail incumbents (backed by large amounts of self-owned generation assets) did not have to fear competition, but the situation has drastically changed. Not only has the scope of their activities extended, but consumers' awareness of green and energy-efficient products and tailored and complete offerings puts pressure on retailers to become "sustainable one-stop shops".

Figure 4: Four key strategic questions for retailers



Source: Arthur D. Little analysis

It is therefore paramount that retailers review or even seek their purpose in order to give customers a reason to advocate for them and employees a monument to build. It is this purpose that defines what the company brings to the world, and therefore, what customers and employees contribute to. Simply providing power (and/or gas) does not suffice.

Having a well-thought-out sense of purpose will enable retailers to ensure consistency and aid in decision-making about where in the value chain and ecosystem they can contribute. Good cross-industry examples are Veolia and Michelin, which understand the importance of this sense of purpose and take the time to define and communicate it. In April 2019, the Veolia Group defined its Purpose articulating the "why", the "what" and the "how", as illustrated in Figure 5.

Not only is it key to reflect on and define the sense of purpose as a reminder of the company's differentiators and sources of value creation, but it is also indispensable to communicate about it internally to employees eager to contribute to a better society. They must also embed it in their culture, as well as externally, aiming to reach customers assessing the company's legitimacy to operate.

We have met many companies that claimed to have worked on their sense of purpose, but that neglected the need to communicate about it; this has led to limited impact in terms of the brand perception and emotional link that the sense of purpose is supposed to create.

2. Where should our company play a role in the ecosystem, and how?

Convergence of industries has brought (electric) mobility, smart devices, telecom services, and even financial services and construction to the retailer's doorstep. Aside from that, the traditional linear energy value chain has been disrupted by new types of players (such as energy service companies and aggregators) and new forms of generation (decentralized generation), which represent both a threat and an opportunity to broaden their offers. This makes retailers question their positioning in the value chain, as well as broadly in the energy ecosystem and beyond.

Figure 5: Sense of purpose as defined by Veolia

"Our business prospers because it is useful, not the other way around. Its usefulness is the source of its attractiveness for its customers, and it is its usefulness which keeps its employees committed and which is the foundation of the loyalty of its shareholders, customers and partners." Antoine Frérot, CEO of Veolia

In April 2019, the Veolia Group defined its purpose, articulating:

WHY

- Veolia's purpose is to contribute to human progress by firmly committing to the Sustainable Development Goals set by the UN to achieve a better and more sustainable future for all. It is with this aim in mind that Veolia sets itself the task of *"Resourcing the world"* through its environmental services business

HOW

- *All Veolia's stakeholders* are informed of its purpose so they are aware of, and can contribute to, an effective implementation
- Veolia *reports annually* on its multidimensional performance through a dashboard that aggregates indicators of the sustainability of the model
- A *stakeholder committee*, comprised of experts from civil society and representatives of customers, suppliers, employees and future generations, issues opinions to the company's management, assisting in achieving the purpose

WHAT

- Veolia provides its customers with solutions that *facilitate access to essential services and natural resources*, and that efficiently conserve, use and recycle those natural resources

VEOLIA

Source: Veolia, Arthur D. Little analysis

Given the increasing number of new players and convergence of industries within the energy value chain, retailers are facing existential questions on where and how to position themselves in this new ecosystem of interconnected actors to provide their own parts of a solution. Indeed, retailers have understood they will not win through single products, services or solutions. Rather, it will be about providing a range of solutions, supported by the right capabilities which will unlock a new pool of value (that was inaccessible in the past, given the challenge to invest in so many capabilities). It will also be about leveraging platforms and partnering with others to create innovative business models.

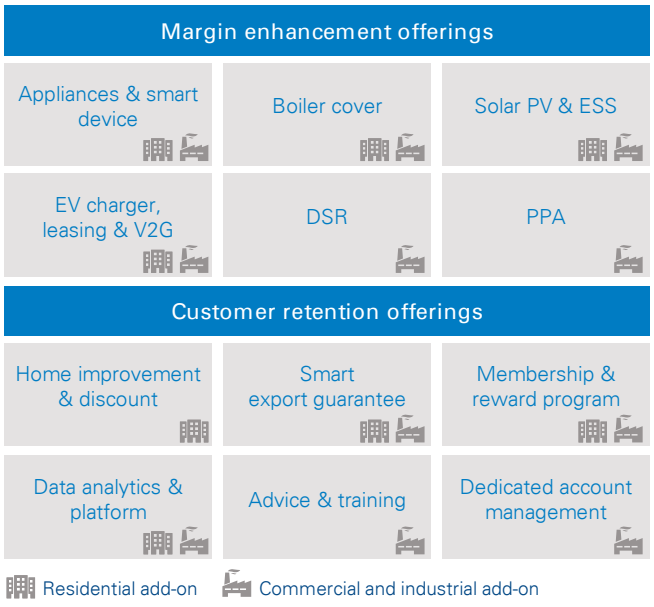
In that context, the retailer of the future will exploit opportunities created by an ecosystem-driven world of collaboration and specialization. It will also leverage its own core capabilities and blend them with those of partners to offer a unique value proposition to the market. Nissan and EDF Group have signed a cooperation agreement to deliver electric mobility together, each leveraging the capability of the other to accelerate their development in this area. While Nissan is responsible for the sale of vehicle-to-grid (V2G)-compatible electric vehicles, EDF Group is in charge of V2G charging solutions and related services.

Similarly, Enel X, Nissan and RSE have launched the first testing program in Italy for the development and demonstration of vehicle-to-grid (V2G) technology, which enables electric vehicles (EV) to store and deliver electricity to help stabilize the electricity grid. The project involves the use of two Enel X bi-directional recharging systems, installed in the experimental RSE micro-grid, which, using a specific control platform, enables the use of Nissan LEAFs for grid stabilization.

As such, retailers will clearly need to decide ***what offers*** they want to propose, and ***what roles*** they will take:

1. **"Commodity energy suppliers"** focus on providing the commodity product itself (power, gas, or both). These suppliers typically do not provide any extra products or services. Nowadays, with active customers and a heightened sense of purpose, differentiation is still possible, in terms of, for example, targeted offerings (young and digital consumers, green and sustainable preferences, housing corporation tenants, seniors, etc.).
2. **"Managed energy services"** have core energy offerings, plus a range of add-on products and services to position them as holistic "one-stop shops". Example add-ons for both residential and C&I (commercial and industrial) segments include PV and/or energy storage system (ESS) installation and management services, EV charging-point installation and V2G services. Example add-ons specifically for C&I are ESCO-type services and aggregation, as well as DSR-type services. We see add-on services, as displayed in Figure 6, which can be segmented according to whether they predominantly lead to increased customer retention or increased margins. Together with dynamic pricing schemes, the integrated "energy offering" can become truly tailored towards the consumer and related add-on products.

Figure 6: Energy retailer add-on offerings



Source: Arthur D. Little analysis

3. **"Beyond energy service providers"** goes beyond the scope of energy to offer a broader portfolio. Products and services might relate to telecommunications, smart home devices, financial services, leasing, etc.

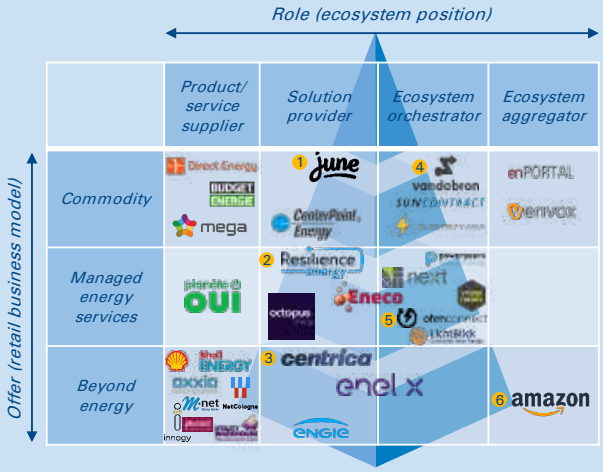
Following another dimension, the retailers of the future will take up their roles in the energy ecosystem, which will range from bare-bones product and service providers to more innovative positions as ecosystem orchestrators and aggregators.

1. **Product/service suppliers** offer no more than the simple product or service to one actor in the ecosystem. In the case of energy retailers, the actors are most often consumers, suppliers and system operators. They compete on price and technology.
2. **Solution providers** combine products and services into entire solutions, for which the added value is higher than the sum of the parts.
3. **Ecosystem orchestrators** leverage existing assets and solutions by orchestrating platforms to create network effects between actors.
4. **Ecosystem aggregators** maximize customer lock-in by aggregating different ecosystems.

In recent years, we have seen many start-ups filling the empty roles in the ecosystem, and incumbent utilities and retailers shifting their businesses to capitalize on these emerging revenue opportunities.

Details of some of these players, as well as other examples, can be found below.

Illustration of players active in the energy retail ecosystem



01 | June – Automatic switching of supplier with lowest price and highest promotion

Solution providers combine products and services into entire solutions, for which the added value is higher than just the sum of the parts – this is in contrast with bare-bones product/service providers, which typically supply just the energy commodity.

June goes beyond traditional price comparison websites by offering a smart dongle and application that measure power and gas consumption. Based on the consumption profile, June continuously looks for better energy contracts on the market and switches the customer automatically. On average, June switches contracts two to three times per year, saving the customer up to €300 annually.

This solution is an example of how a start-up, founded in 2016, revolutionized interactions between retailers and customers while still creating value for the customer based on the commodity only.

02 | Resilience – Providing prosumers with hardware, software and contracts to produce, store and sell

UK start-up Resilience aims to convert UK homes into personal power stations. By choosing one of the packages, the customer receives a 2–4kW PV installation, a 4–12kWh battery installation, and access to the application. The added value lies in its optimized savings by learning the usage

behavior of the consumer and storing or selling energy back to the grid to maximize arbitrage.

This area knows the most activity, as utilities are increasingly moving into the solution space, trying to lock the customer in by bundling multiple products and services.

03| Centrica – Shifting from a "gentailer" to a solution- and service-oriented retailer/aggregator

The large traditional utility Centrica is shifting its focus towards service-oriented business, most notably in its Centrica Business Solutions and British Gas brands. The first offers a complete portfolio of ESCO services to businesses, while the latter offers energy, home services and smart home solutions in the residential sector. To achieve this positioning, Centrica has acquired multiple companies, which span from smart home devices (AlertME, FlowGem, Hive, etc.) to aggregation (REstore).

Centrica is one of few examples of dominant utilities making large shifts in their business models through acquisitions to focus on service solutions. As an illustration, Centrica has sold several of its centralized generation assets.

04| Vandebron – A peer-to-peer marketplace for green energy

Ecosystem orchestrators take their inspiration from the platform economy. They develop platforms that can create and orchestrate ecosystems to produce network effects using the actors' assets.

The Dutch supplier Vandebron is such a platform creator. It gained rapid success by offering a platform on which consumers could select one or more sources of green energy, often prosumers or small independent power producers (IPPs). Consumers benefit by having a greater sense of control over the sources of their energy, whereas IPPs, and especially small prosumers, benefit by having an alternative route to market. In November 2019, Vandebron was acquired by incumbent Essent, but it will remain a separate brand and entity. Similarly, several start-ups, such as SunContract and Electrify, have created peer-to-peer markets using blockchain technology to facilitate trading of renewable energy among communities.

05| OhmConnect – Bringing the power of DSR to households

Californian start-up OhmConnect notifies household consumers with smart meters when consumption is expected to peak. If, during the notification period (which lasts one hour), the consumer lowers their consumption, they are remunerated. The process is similar to traditional large-scale demand-side response (DSR), in that OhmConnect works together with the transmission system operator and utilities by offering them flexibility.

This is just one of many examples of recent platform-like business models. Traditional aggregators of generation and DSR fall under this category. Other examples include companies that create platforms to facilitate crowdfunding of renewable assets. Consumers that invest typically receive part of the generation of the asset, while the asset itself is owned and operated by the company.

In Europe, with the impending obligation to offer at least one dynamic pricing tariff, we suspect many new solution-oriented business models will flourish.

06| Amazon – The usual suspect setting foot in the world of energy through smart home devices

To date, there is no clear player taking the role of ecosystem aggregator that includes energy as part of the ecosystem. Several voices in energy markets claim that big tech players are well placed to launch such efforts in the near future, for the following reasons. Firstly, customer centricity, the main pain point traditional utilities fail to cover, is in their DNA. Not only are their customer-facing platforms optimized and trusted by millions, but the amount of data and knowledge they have about their customers would be of huge help in creating supplier businesses. Secondly, as entities in the public spotlight, many big tech companies committed to climate initiative the RE100, which means they aim to source energy from 100 percent renewable generation by 2025. In their efforts, Apple, Facebook, Google and Microsoft are getting involved with power-purchase agreements (PPAs) and even acquiring their own generation assets. Through this they are gaining experience and could set up assets for future retail activities. Lastly, the widespread offerings in smart home devices are already used as a first entry point in the energy ecosystem.

Amazon's smart home assistant, Alexa, is already marketed together with British Gas's Hive offering, Enel X's HomiX smart home solution, Octopus Energy's Agile offering, and many others. It is speculated that the big tech companies will experiment more in the energy ecosystem once energy markets are deregulated more in the US, their home field.

3. How to build an organization that combines scale and productivity with speed and creativity?

Given a retailer's sense of purpose and targeted role in the ecosystem, a key question is ***how*** it will reach that state in the future. Although many retailers almost exclusively focus on "scale and efficiency", today they must seek growth in innovation, creativity, and collaboration — or risk failing to get to their envisioned ecosystem positioning.

Ambidextrous companies are those that excel at finding this fine balance between "scale and efficiency" and "speed and creativity" – and they are few and far between. However, we are seeing more and more large retailers attempt to become ambidextrous, often through acquiring successful new market entrants that carry "speed and creativity" in their DNA (for example, the acquisition of REstore by Centrica).

From our experience, it's important to give the newly acquired or created business its own distinct governance and incentives and allow it to cannibalize the traditional business of the mother company. This is exemplified by Enel X, which developed an all-new digitalized offering by establishing a separate, fully independent entity with its own separate management team.

4. How do we become truly digital and tap the potential to improve operations efficiency and increase revenue? What should our priorities be?

Multiple business implications are driven by the emergence of digitalization within the energy industry.

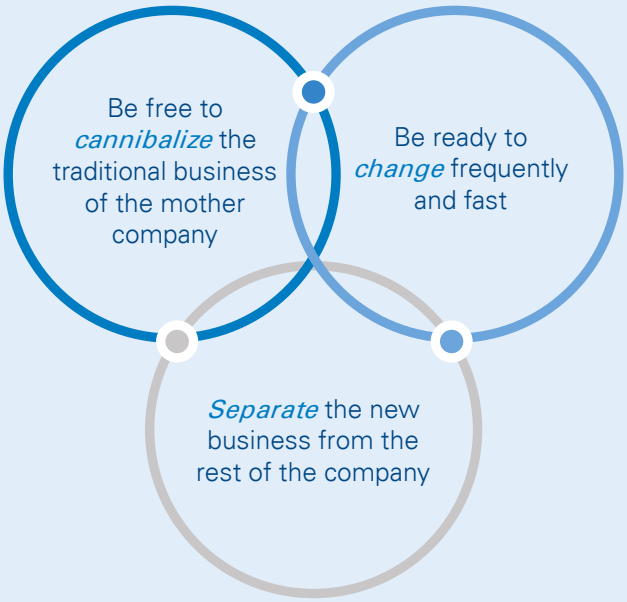
New product offerings – New products and services, enabled by an innovative digital ecosystem and technologies, are emerging to create new revenue streams and compensate for stagnating core businesses.

Operations optimization – Digitalization of operations and processes has enabled some players, mostly new entrants, to achieve operational excellence through implementation of cutting-edge, scalable back ends that can combine forecasting, procurement and customer-handling, as well as to optimize costs, which leads to competitive pricing.

Customer engagement – Developing innovative offerings and ensuring customer-friendly and efficient processes and operations are essential steps to convince, acquire and retain customers. Digitalization plays a paramount role in seamless customer journeys if leveraged to the fullest.

Figure 7: Enel X strategy

"If you keep the innovative stuff within the traditional company, the legacy business will feel threatened; you need to establish a separate and fully independent entity with its own management." Francesco Venturini, CEO of Enel X



Lessons learned from Francesco Venturini, following the creation of Enel X, which provides new digitalized products and value-added "non-commodity strictly related" services, such as energy efficiency, demand response, electric mobility, the Internet of Things (IoT), and optical fiber

1. Better to *cannibalize* your own business before your competitors do
2. Need to move fast, *changing* the organization to keep up with business needs and context; train people in frequently *shifting* viewpoints and habits
3. If you keep the innovative stuff within the traditional company, the legacy business will feel threatened. Establish a *separate* and fully independent entity with its own management

enel x

Source: Enel X, https://energysmart.enelxnorthamerica.com/one-year-enel-x-5-most-valuable-lessons-learned, 2018, Arthur D. Little analysis

Players such as Octopus, OVO Energy and Opus, active in the UK retail market, have developed their business models based on AI and digitalization, capitalizing on data to improve customer experience and internal processes. In less than four years, Octopus Energy grew its customer base from nothing to 1 million customers, mixing organic and inorganic growth through differentiated positioning and excellent customer experience. This tech-savvy retailer with smart tariffs proposes a smooth experience through AI systems, which allows it to interact with customers via different channels (web, mobile, smart meters). Aside from obvious internal benefits from an operational perspective, Octopus Energy has generated extra revenue by leveraging its "Kraken platform". Marks & Spencer, a white-label brand, recently chose Octopus' energy over the usual incumbent for its energy operations, mentioning that the technology platform was a key decisive factor. Good Energy has also announced using the Kraken platform as of 2020 for its customer service and billing. It is the first time a retailer has used a rival's back end in the UK.

Incumbents need to reflect on their digitalization journeys to (1) expand their offerings toward increasingly demanding customers who desire personalized services, and therefore pursue new growth opportunities (such as through creation of a 100 percent online brand), (2) improve their operations to reduce costs and (3) improve customer experience. To determine where their focus should be, retail organizations need to assess their maturity on those three fronts.

3. Key recommendations

Relying on ecosystems and digitalization to access new pools of value, reduce costs and improve operations and customer experience

The traditional dominance of incumbent energy retailers is under pressure as challengers across industries grab market share with disruptive services. While new entrants' business models mainly rest on digitalized and innovative operating models and services, traditional players struggle to transform and think outside their core businesses.

Considering their profitability levels nowadays and the increasing intensity of competition, energy retailers should, on one side, focus on making sure they have the right partnerships to unlock new pools of value that require new capabilities. On the other side, they should seek to leverage digital and artificial intelligence to reduce costs, create new sources of revenues through new offerings and improve customer experience.

In this dynamic environment where many industries converge, Energy retail CEOs should re-define and leverage their sense of purpose to guide them in their investment and partnership decisions while respecting the long term commitment of the company towards the society, giving employees and customers confidence in the company for the values it represents.

Authors

Kurt Baes, Andrea Romboli, Florence Carlot, Loic Vervaeke

www.adl.com/ EnergyRetailTransition

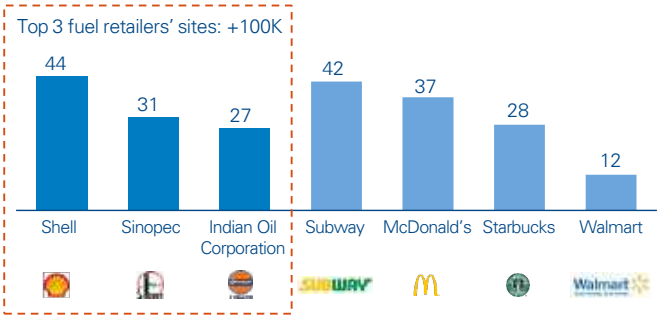
The forecourt of the future

With a disruptive lifestyle and technological changes ahead, the fuel retail business will need to create a new customer experience on the forecourt

The traditional forecourt model is at its inevitable end. Electric vehicles (EVs), autonomous cars, data analytics, and the Internet of Things (IoT) are only a few of the emerging technologies threatening the classic fuel-station customer experience. What will the next-generation forecourt scene be like?

Transformation of the fuel retail business should not be underestimated. Its huge dimension (over 300,000 sites globally) implies that it will not only impact existing players, but also revolutionize its customers and adjacent markets.

Number of sites (in thousands) for major retail players – 2019



Source: Arthur D. Little analysis

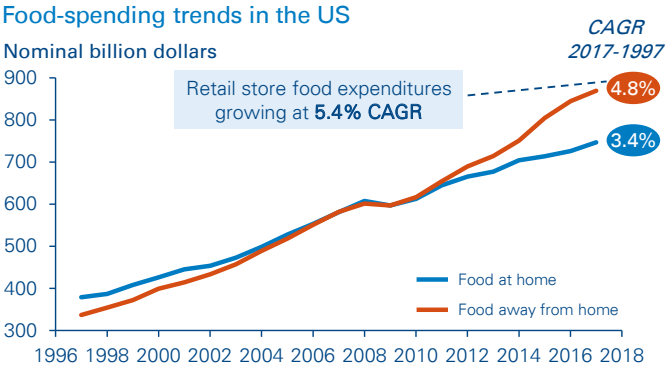
When predicting the near future at local fuel stations, key trends concerning how we commute, eat and shop will be the core drivers that ultimately shape the forecourt.

Increased demand for grab-and-go eating – As the world becomes faster paced, time and efficiency are becoming a game changer for retail businesses. Busy agendas demand that services become quicker and better. People now eat a lot less at home, which makes convenience shopping and "grab-and-go" eating a major global trend. In the US, food spending away from home has surpassed that for food consumed at home since 2010. Particularly, customers now prefer healthier food alternatives to the usual fast-food burger or doughnut. Additionally, more people are working and interacting outside of formal office settings, traveling to provide services, and alternating sales with administrative tasks "on the road" – taking advantage of fuel retail sites for higher efficiency.

A shift in the mobility energy mix – The transport sector is shifting. It is leaving behind a petroleum-dominated segment and looking towards cleaner sources of energy, such as gas, hydrogen, and electricity.

Demand for eco-friendly outlets – Awareness has been growing among consumers about their carbon footprints, which is making their purchasing choices greener. In response, retail sites are adapting their buildings into eco-friendly layouts, pushing for sustainability and minimalism, and publicly committing to more conscious use of energy and materials.

Food-spending trends in the US



Source: Arthur D. Little analysis; USDA

Hyper-connected customers – Smartphones have become indispensable in our lives. We rely on them for almost everything: choosing routes, estimating travel times, ordering

and paying online. The trend is irreversible. Users' ability to perform a variety of tasks over their smartphones is not only beneficial for them, but also for businesses, as the businesses can access enormous amounts of data generated every minute by consumers. The stream of information leaves us hyper-connected, which allows for new features in the retail world, such as omnichannel and individually targeted mobile marketing.

Quest for easier living – Fuel retail has been commoditized, with consumers choosing between one retailer and another by price, location and availability of specific services. People are more likely to decide on one station over another for compelling reasons, and while location will remain a key factor, the presence of diverse convenient services is becoming more important as a differentiator. Consumers are reaching out to services that ultimately make their lives easier, but preferences are not the same for everyone.

The forecourt of the future

In order to remain relevant and thrive in such a context, the forecourt of the future should consider the following key topics.

Diversification of energy offering

Forecourts of the future will have to offer a wider range of sources (electricity, natural gas/CNG, gasoline, diesel, LPG, biofuels, hydrogen). This will require adjusting their real estate layouts (tanks, batteries, pumps, etc.) and coming up with smart strategies to provide smooth fueling services to different customers. In Japan, for example, cars are fueled from hoses coming down from the ceiling, with no pumps occupying space on the forecourt. We expect "no petrol" stations to emerge, and countries such as Germany, UK, Japan and Korea will lead hydrogen supply growth.

Traditional offering adapted to a broader set of customers

Stations have evolved from fuel-exclusive businesses to mini supermarkets or convenience stores where consumers can buy snacks or even full meals. The forecourt of the future should maintain the traditional offering, while adapting to cater to a broader set of customer requirements. Some customers might rush in to refuel, some may enjoy cups of coffee while they wait for their EVs to charge, some will stop by for quick lunch breaks, and others could settle at tables and work for a few hours. Fuel stations will act as meeting points for various types of consumers, each having a different purpose.

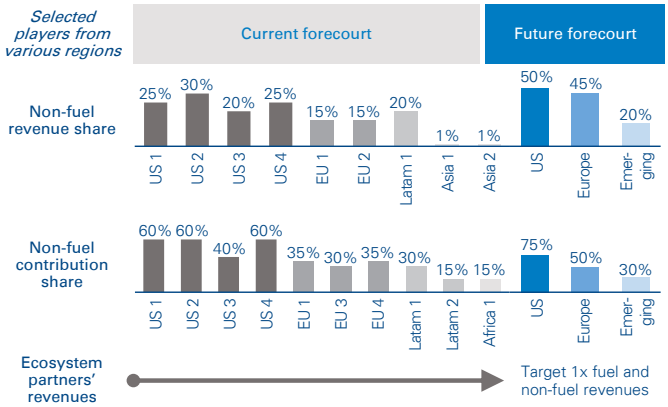
Developed countries are already experiencing about half of their fuel stations' profits being non-fuel related. Emerging countries still have lower non-fuel contributions, but will eventually catch up because non-fuel sales is a faster-growing segment. (For example, China's Sinopec and CNPC are undergoing 20 percent-plus annual growth.) The petroleum-dominated retail world is fading. Shell has set an ambitious target of reaching 50 percent non-fuel profits globally by 2025.

Attending to multiple customer needs

	What are their needs?	What to offer?
Flex-working	▪ Wants a comfortable place to work outside home ▪ Values ambience and experience	▪ Sophistication in food & beverages, coffee and bakery ▪ Digital and value-added services ▪ Exclusive/VIP area ▪ Frequent-visitor deals
Agile driver	▪ Wants to streamline the fueling process ▪ If possible, avoid getting out of the vehicle	▪ Access to priority/fast-lane ▪ Package collection from e-commerce ▪ All-in-one e-payment and transactions
Digital native	▪ Wants to interact through their smartphone	▪ Mobile app platform ▪ Digital services ▪ Targeted marketing ▪ Package collection from e-commerce
Socializing	▪ The station is a meeting point	▪ Will probably spend in convenience store and/or coffee and bakery ▪ Entertainment services ▪ Parking
One-stop ecosystem	▪ Wants efficient use of time ▪ One stop for multiple purposes	▪ Convergence of retail stores ▪ Banking, pharmacy, grocery, laundry ▪ Package collection from e-commerce ▪ Cross-selling bundles ▪ Parking

Source: Arthur D. Little analysis

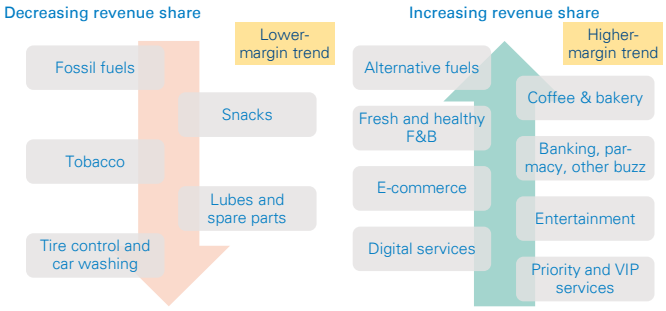
Non-fuel revenues and contribution shares from a selection of players



Source: Arthur D. Little analysis

As the customer experience becomes ever more complex, retailers will have to modify their infrastructure into modern, clean buildings with innovative interior designs, using environmentally friendly materials and smart technologies to create pleasant micro-climates for people to enjoy. Fuel stations will convert into multi-use ecosystems, with separate relaxing spaces for those who want to read or work, clean and bright areas for eating, and even green terraces for social gatherings. Bigger parking lots will also be necessary to cater for larger crowds that stay for longer periods. Fuel stations possess a key asset which retailers can leverage to build a new ecosystem containing multiple businesses: real estate. In this context, customers will be able to enjoy a wider set of services. Entering the e-commerce world is a likely scenario as well, and the presence of omnichannel transactions will be a key feature for the future of fuel retail forecourts.

An omnichannel retail ecosystem



Source: Arthur D. Little analysis

Fuel stations play a critical role as infrastructure enablers in facilitating the EV transition. Availability of charging points is one of the main drivers of EV adoption. While retailers offering charging points will certainly push the EV market, their own businesses could contribute by capturing higher margins for EV charging than for fuel. Station owners will need to revisit their business models and consider whether to enter the electric market independently or by partnering with third-party charge-point operators (CPOs).

Yet, oddly enough, the forecourt will no longer be the only place for fuel filling. As digitalization moves forward and enables better logistical services, it is no longer consumers approaching businesses, but rather, the other way around. This is also true for fuel retail: some retailers already provide fuel delivery. Shell's TapUp application offers scheduled fueling at customer locations. This opportunity is being seized by new entrants that sell on-demand fuel at competitive prices, such as Zebra Fuel in the UK, as well as WeFuel, Filld and FuelMe in the US.

Connected cars and automation

Although it could take decades before autonomous vehicles become a common sight on our roads, car manufacturers are already embracing big changes as more and more models benefit from "connected services". Payment will not be the only automated service; so will some of the core forecourt processes, such as pumping fuel and car maintenance.

Your future car will be able to locate your nearest station as you run out of fuel, going so far as to check whether the station has the type of fuel you usually buy in stock, or even how long the waiting time will be. Cars and pumps will work together. Cars will be able to transmit the required fuel volume upon arrival, the pump will autonomously start filling, and with a one-click, in-vehicle payment, there will be no need to leave the car! Even vehicle maintenance services could be automated, such as checking engine oil, tire air pressure and lubricants.

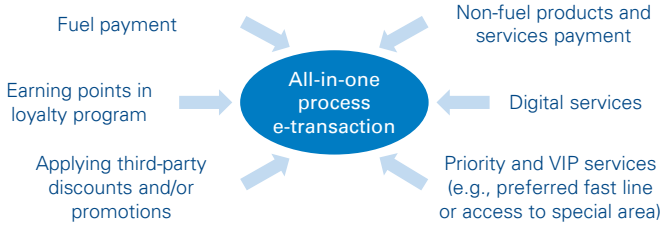
Shell has partnered with Jaguar Land Rover in the UK and GM in the US, offering an in-car payment system at its stations. This allows its customers to pay for their fuel from their cars' touchscreens, without having to swipe credit cards or use their phones.

All-in-one process e-payment

The world is shifting towards easier and quicker payment solutions using mobile applications, and fuel stations won't be left out. Retailers will develop their own apps with multiple mobile payment alternatives, which will allow customers to control their fill-up experiences through their smartphones. These apps will also have convenient features such as feedback, receipts, transaction history, rewards through loyalty programs, and third-party discounts, also processed automatically.

Shell has been a pioneer in this area, with its "Fill Up & Go" app in the UK, which is powered by PayPal and now accepted at more than 1,000 stations. ExxonMobil has launched its "Speedpass" app, available at more than 6,000 stations across the United States. These enable customers to link the apps to their loyalty programs and earn reward points with every purchase. Alternatives have also been introduced, such as QR codes.

Convergence on all-in-one process e-transaction



Source: Arthur D. Little analysis

Behavioral analytics for one-to-one marketing and service level

Connected cars plus data analytics will lead to predictive customer behavior, tailor-made services and targeted promotions. Loyalty programs will become highly effective. By using machine-learning technologies, customers will be able to prepare their fuel recharges, groceries or even coffee pre-orders easily – and access better prices customized for these. In the US, the GasBuddy app brings targeted offers to consumers who drive past stations subscribed to this service. This is facilitated using location-based marketing, and boosts retailers' c-store sales.

Data analytics creates the opportunity for retailers to profit from increased revenues by cross-selling with advanced one-to-one marketing strategies and dynamic pricing. It also allows them to reduce operational costs with automated stock management and maintenance.

One-of-a-kind service station models

We believe fuel stations will adopt some of the aspects mentioned above. However, we recommend each retailer identify its strengths and competitive advantages, as well as consider its location and the type of community it is engaging with in order to define the most suitable business model in these new market conditions. These types of service stations have already started to converge around a few main models (listed below), but other models will materialize.

- Community center station – full service, a wide range of fuels, a meeting point for multiple customer segments (omnichannel)
- Urban express c-store – a small convenience store with basic groceries and snacks and a limited fuel offering (for example, one EV charging point and one fuel pump)
- Multi-use highway station – spacious and modern stores with multiple areas and fuel-based revenues
- Long-haul station – resting and service areas for drivers and maintenance, as well as other fleet management services for trucks

Although this might turn out to be a medium-term trend, we believe service stations will stretch their business models further, becoming ever more tailor made for their types of audiences. Better customer segmentation with a targeted offering will allow each station to run a model of its own.

Insight for the executive

- Take the lead in industry convergence – leverage real estate assets and long-lasting relationships with dealers to attract new players.
- Find a strategy to steer customer-purchasing decisions, involving both own and third-party products.
- When partnering (e.g., for loyalty programs), make sure to gain full access to the generated customer data.
- Customer experience is key – cross-selling to increase share of wallet from the fuel customer's total daily spending.
- Revisit potential for a new customer base – create the right service station model for the needs of various clusters.

How can Arthur D. Little support key players?

- Reviewing and optimizing fuel (and non-fuel) portfolio.
- Planning fuel distribution and retail network transformation.
- Defining future retail-model types and scope of services for return-on-capital optimization.
- Technology selection and business cases.
- Supporting partner selection and developing collaboration strategies.

Authors

Daniel Monzon, Catalina De Stefano, Carlo Stella

www.adl.com/ForecourtOfTheFuture

Arthur D Little

Electric mobility impact on downstream oil business

Threat or opportunity?

Executive summary

Mobility has been dominated by combustion engines and fuelled by oil companies. Regulation, customer demand and technological development, are pushing electricity as a mobility power source, which will inevitably impact the downstream oil business. While the traditional business model is under threat, new opportunities arise.

There is still uncertainty over the potential of electric mobility and the impact it could have on certain businesses, but we have deep-dived and estimated the impact on the downstream oil business.

- Conditions are given for EV deployment to accelerate.
- EVs' impact on refining will be highly heterogeneous among regions.
  - Some refiners will face tighter economics since they will have to find markets further away.
  - More shutdowns will occur in low-scale and/or low-conversion refineries.
  - Less impacted regions will only see displacement of oil products' imports, with minor impact on capacity utilization
- There will be relative excess of gasoline due to further challenges in the demand mix.
  - Part of this will find a market as naphtha.
  - Gasoline will face lower spread versus diesel.
- New refining capacity additions will come in the form of "oil to chemicals", limiting production in the light vehicles segment.
- Oil companies will struggle to retain their share of the mobility market.

Arthur D. Little has previously conducted studies on EVs, and now analyzed and simulated the potential impact on downstream oil business. In this document we will discuss:

- Refining capacity impact;
- Refining demand mix impact;
- Petrochemical business impact;
- Fuel retail business impact.

1. EVs are coming to stay

It is no news that electric mobility has been growing and advancing. The first commercial electric cars appeared in 2008, and their adoption rate grew slowly until recent years, when it broke the million-units-on-the-road mile, particularly due to developments in China, the US and Europe.

Its increasing penetration has been encouraged by four main stakeholders: 1) government entities, which are increasingly recognizing the importance of reducing CO_2 emissions and air pollution; 2) OEMs[1] and equipment/service providers, which are creating/reshaping business opportunities; 3) consumers, which are witnessing their purchasing barriers eroding; and 4) infrastructure enablers, which are eyeing additional sources of revenues.

The EV market: Drivers and challenges

Let's analyze the EV market's drivers and challenges in more detail:

Governmental entities' commitments

As showcased by the Paris Agreement, most governments are making efforts to reduce their carbon emissions. In addition, eight major nations signed the Government Fleet Declaration in 2016, pledging to increase their shares of electric vehicles in government fleets and calling for other governments to join them. This effort goes hand-in-hand with the ambition of decarbonizing power generation by switching first coal, and then oil products, to natural gas, as well as increasing the share of alternative energy sources.

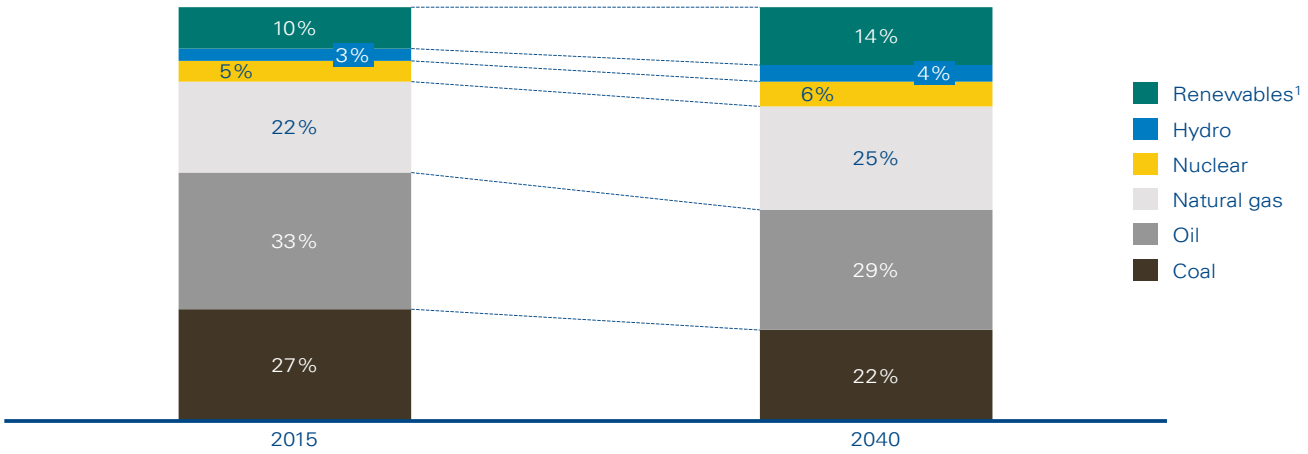
Similarly, metropolises and governments have started to address concerns arising from high levels of air pollution by applying policies to reduce fossil-fuel vehicles in cities, and even announcing bans on internal combustion engine (ICE) vehicles.

Overall, 14 countries have expressed intention to execute ICE bans. However, some of these bans are not pursuing a country-wide scope, and their commencements are dispersed from 2018 to 2040 so it will take some years after implementation to replace significant parts of running vehicle fleets.

OEMs' regulatory commitments and opportunities

Car manufacturers are in a peculiar situation – they need to balance their strategies between regulatory forces and business-model opportunities. Several large OEMs have announced plans to electrify large parts of their vehicle portfolios (Volkswagen, General Motors, Renault-Mitsubishi-Nissan, among several others). In this context, new players in the value chain constantly appear to compete and get shares of the new market, stimulating investments in technology and driving costs down.

Figure 1: Energy demand mix forecast



1 Non-traditional renewables, including biomass and biofuels
Source: Arthur D. Little analysis

1 OEM= Original equipment manufacturer

Eroding consumer purchase barriers

A few years ago, electric vehicles were perceived as naïve means of transportation for extremely wealthy people with deep environmental concerns, and far from attractive to mass customers. An Arthur D. Little study from 2016 that included thousands of consumers in automotive core markets confirmed that the main barriers to purchasing electric vehicles were their higher prices compared to those of traditional vehicles, the limited operating range, and insufficient charging solutions. However, these obstacles are constantly eroding, and will eventually disappear. Li-ion batteries are still relatively expensive and add up to 35–40% of a vehicle's cost. However, their cost has been decreasing exponentially. We expect the cost of EVs to reach parity with those of conventional vehicles between 2025 and 2027, and even outmatch them later on.

Autonomy range and charging time

Compared to that of oil-fueled vehicles, EVs' autonomy range is still limited. While top-notch cars surpassing 400 miles at full charge exist, "affordable" tier vehicles (<30k USD) are still between 100 and 200 miles.

Furthermore, EVs introduce a new variable to the customer experience: charging time. Even though there are fast-charging technologies available and increasing capillarity of charging infrastructure, the charging time-autonomy range equation is still poor against fossil-fueled vehicles. Besides current fast-charging technologies come at a cost in terms of battery lifetime. However, if more powerful energy storage technologies reach commercial feasibility it can be a game-changer.

Interest from infrastructure providers

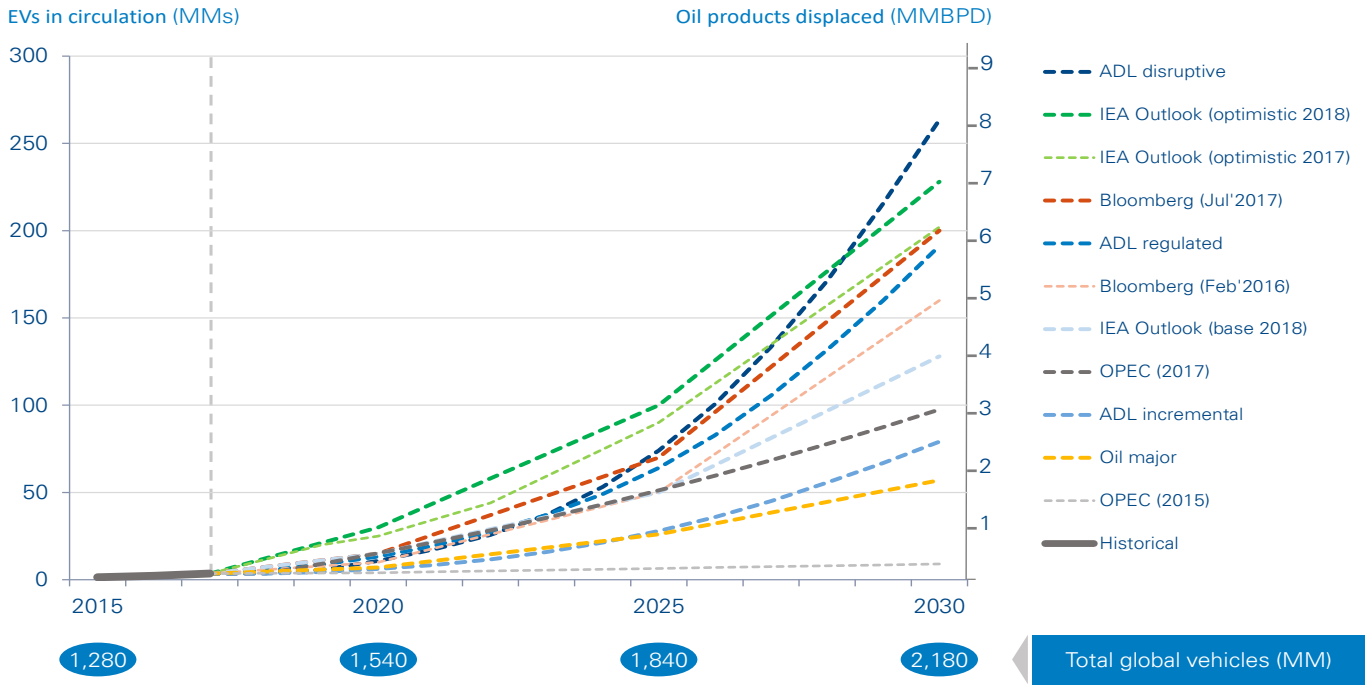
Infrastructure providers are increasingly looking into EVs as a source of additional revenues and embracing the cause. Utilities are increasing their sales through EVs, as well as using them to better manage their networks. Large retailers are using charging stations to attract new customers, parking operators are adding charging services to their offerings, and highway operators could add electric charging station rights to their benefits.

2. EV potential

When will EV deployment boom and how exponential will its growth be? There are multiple views on this issue, but even the more pessimistic and traditional predictions agree that EVs are coming. Market analysts update their forecasts more in favor of EVs every year, and some have even significantly underestimated their first forecasted years.

deployment, restricted by purchasing power and the already-limited capacity of electricity grids. Less economically developed countries usually have lower carbon footprints per capita, which implies less pressure from international regulators. Moreover, these regions, on average, have the oldest car fleets; hence, their eventual replacement will be even slower unless there are serious incentives from local governments.

Figure 2: EV fleet (MMs) forecast to 2030 and oil products displaced (MM BPD)



Source: OICA, IEA EV Outlook 2017/2018, National Renewable Energy Laboratory, Bloomberg, OPEC, BP, Morgan Stanley, Arthur D. Little analysis

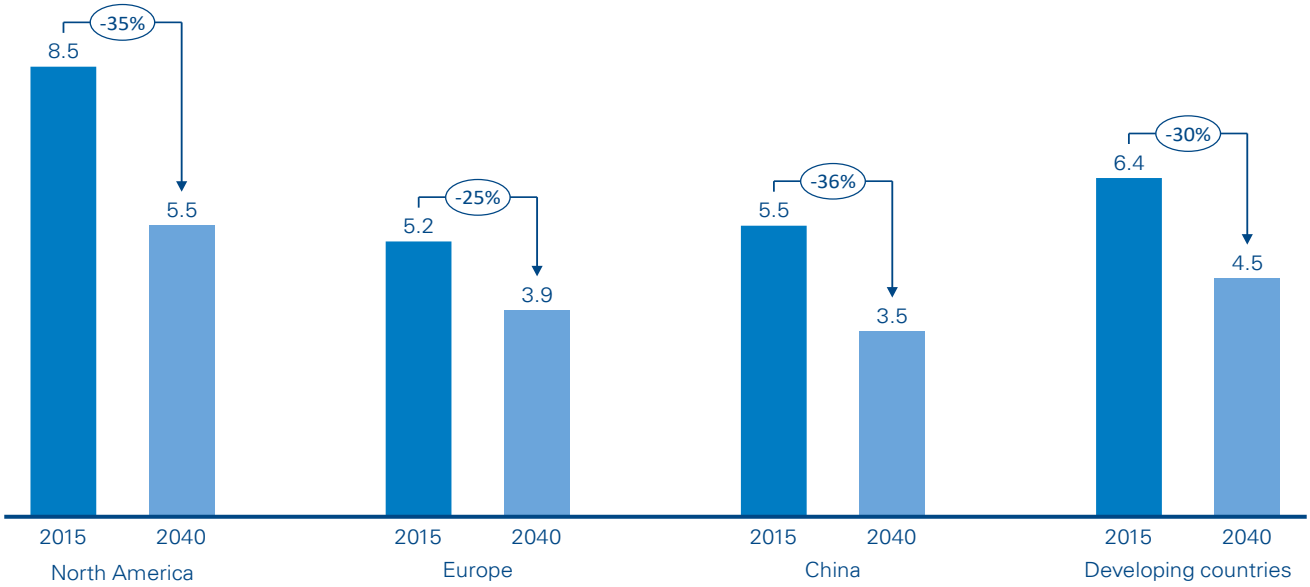
Nonetheless, it will take some time for EVs to have real impact on the global fleet since replacing parts of it will take years. Besides, the fleet is getting older every year.

Growth will be extremely uneven across regions. Europe and North America will lead the way, as they already have willingness from the demand side, government support sustaining growth through subsidies, and funds prepared to invest in charging-network infrastructure. Development in Asia, especially China and India, will be dependent on government policies due to poor air quality in major cities; purchasing power in these countries imposes limits on development of "natural" or organic demand.

The rest of the world (i.e., the rest of Asia-Pacific, the Middle East, Latam and Africa) will see much more moderated

However, EVs are not the only trend affecting oil companies' business: vehicle efficiency and shared mobility are adding to the equation. Gasoline fuel efficiency is expected to reduce fuel consumption by at least 25 percent between 2015 and 2040.

Figure 3: Evolution of new light-duty cars' gasoline fuel efficiency by region (lt/100km)



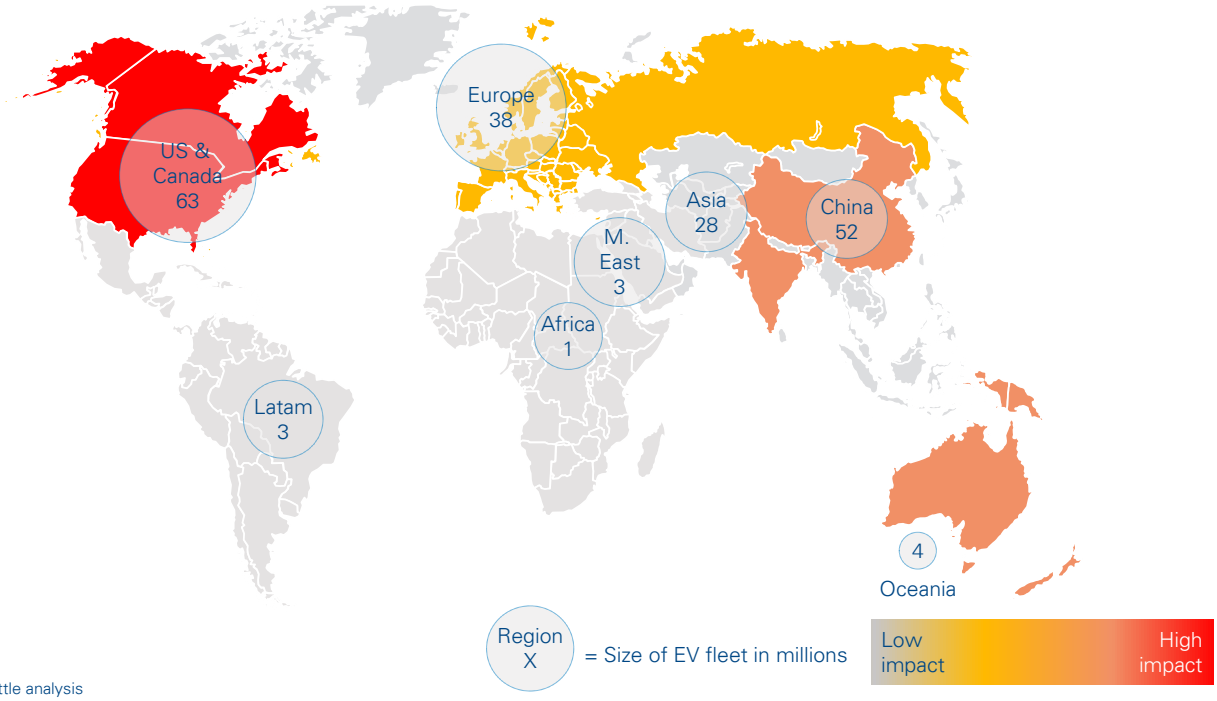
Source: OPEC, Arthur D. Little analysis

The increased adoption of shared mobility policies and solutions (inclusive of public transportation) in large metropolitan areas is drastically reducing the number of cars on the road, and hence energy demand for transportation.

Globally, we expect displacement of up to 5–6 MM BPD of oil products by 2030. In the "ADL regulated" scenario from the previous chart, we simulated that all countries' commitments were met in a timely fashion and non-explicitly committed countries experienced slightly optimistic deployment. As a result, there will be almost 200 MM EVs in circulation, representing 9 percent of the global fleet and 21 percent of global sales. However, deployment and its consequential displacement will be uneven across regions and split disproportionally among fuel types.

We will analyze the possible impact on refining capacity, refining demand mix, petrochemical business and fuel retail business.

Figure 4: Number of EVs by region and impact on oil consumption 2030



Source: Arthur D. Little analysis

3. Impact on oil business

Oil consumption grows at about 1 percent every year and will keep growing globally, but unevenly. Its growth is mainly driven by in-land trade, international trade, increasing vehicle penetration and industrial growth in general (and petrochemicals in particular). So, said global growth will come largely from regions where these drives are to be further developed.

Refining capacity impact

Petroleum refining industry is going through a structural transformation. Regional capacity vs demand unbalances have deepened in recent years, Middle East and Asia projects are the new industry pacesetters in terms of scale and configuration, tightening fuel specs are eroding value of existing capacity and forcing refiners to invest with uncertain returns.

As mentioned before, shared mobility and vehicle fuel efficiency combined with displacement of fuel oil by natural gas already pose a challenge to the refining industry.

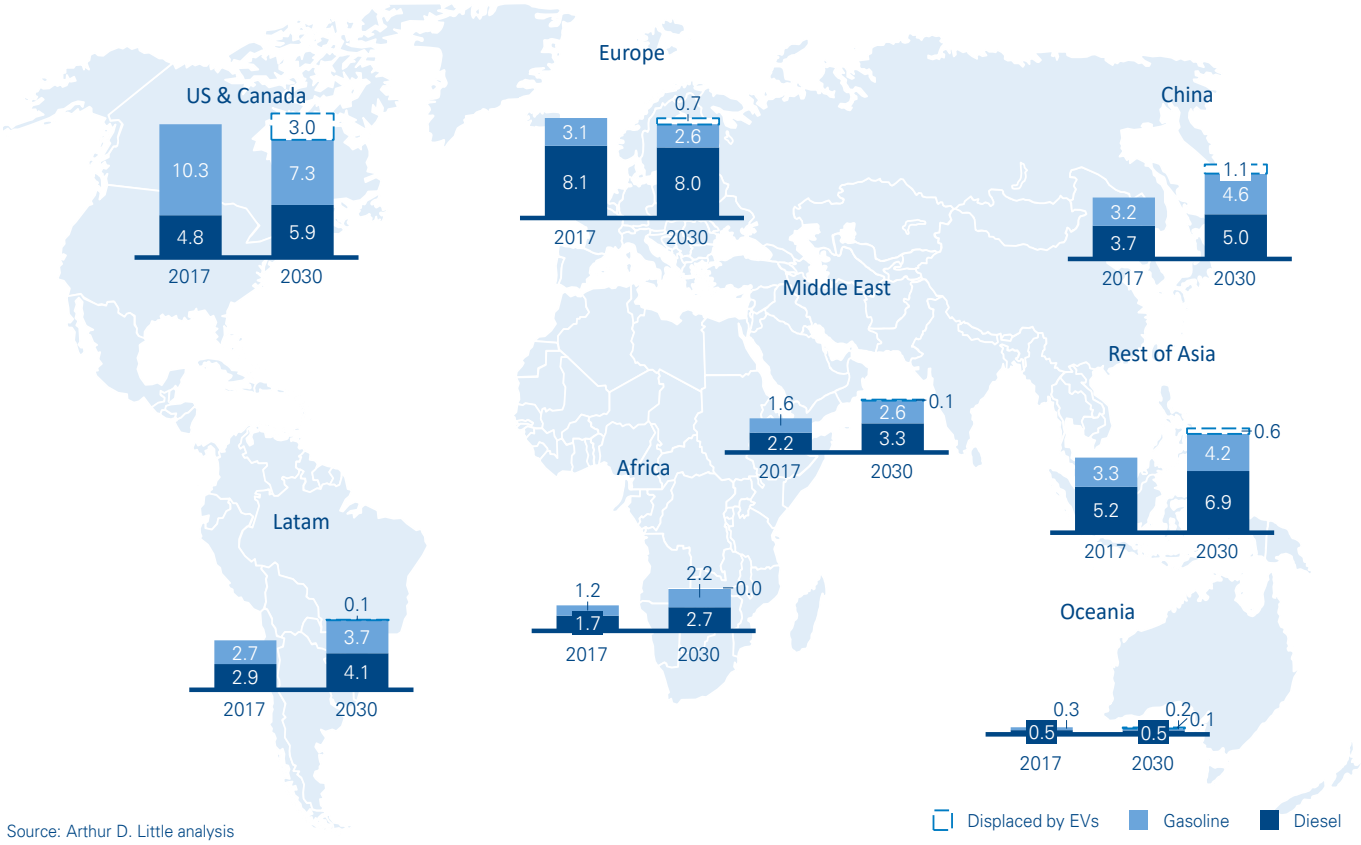
Since mobility will keep growing, so will energy to supply it, and we expect EVs to take a portion of that growth. Yet, it will drive down fossil-fuel consumption in specific regions

EV penetration will accelerate refining capacity crisis, especially in Europe, with more refineries running at low utilization rates and more candidates for closure, primarily short scale or limited conversion capacity ones.

Nevertheless, in fuel-importing regions, it is difficult that EVs will end up affecting refiners' price parities on their products. For instance, we estimate that Latam will be importing about 2 MM BPD of gasoline and diesel together by 2025, and to displace that demand there will need to be around 50 MM EVs on the road. There are almost 140 MM vehicles in the region, with average lifetime of over 20 years. Even if 100 percent of sold vehicles are electric, it will take five to six years to displace imports. And for most countries in the region, we don't foresee significant electric participation in vehicle sales before 2025.

In Asia, a fast growing demand and importing region, the impact on refining capacity will take time.

Figure 5: Current and projected on-road demand for oil products (MM BPD)



Source: Arthur D. Little analysis

Refining demand mix impact

There is no doubt that the gasoline supply-demand balance will be affected, as well as that of diesel, albeit more moderately. For alternative markets, it is worth mentioning that:

- Part of the refinery streams going into the gasoline pool can and will be placed in the petrochemical market. Hence, refinery margins will be increasingly influenced by the petrochemical supply-demand balance. In any case, we expect that refinery naphtha used as petrochemical feedstock will see limited price differentiation against crude oil. Moreover, such balance is going to see greater supply of virgin naphtha coming from increasing condensate production from gas fields.
- Displaced diesel will find a market as marine fuel, especially since IMO regulation at 0.5 percent sulfur content will be established (if not entrenched by the time EVs represent a real threat) and some shippers will be willing to switch to middle distillates.

Such effects will challenge refining capacity and product mix, particularly where the current diesel-gasoline unbalance is to be deepened.

For the rest of refinery products, we do not expect major challenges due to greater electric mobility participation. Methane and ethane are usually used as self-consuming refinery fuel or fed to the petchem industry. LPG will continue to supply off-the-grid population as cooking fuel, and any surplus will continue to be a valuable petrochemical feedstock.

For heavier products, there will be no choice but to convert them, since their demand is shrinking every day, and this will happen mainly in scale-reasonable refineries (over 130–150 KBD).

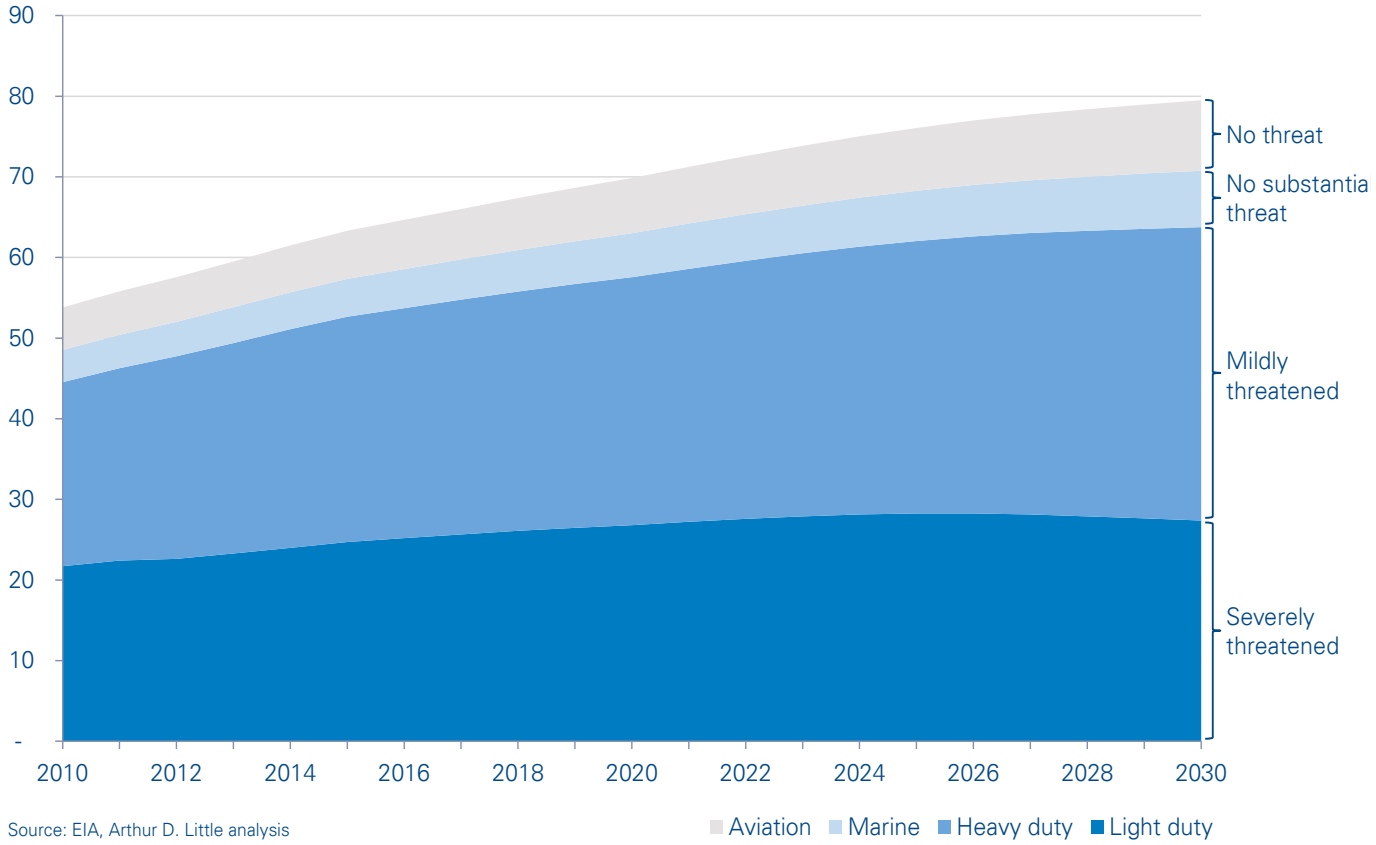
Electric mobility will surely have greater penetration in the light-vehicles segment, which is mostly gasoline fueled; thus, the impact on gasoline consumption will be greater.

This due to:

- Lower lifetime of light-duty fleets
- Lower weight of economics for individuals
- Higher fuel taxes for light-duty vehicles

However, we also foresee increasing electrification in heavy-duty mobility, especially urban buses and marine mobility – although marine mobility is less proportionate and still in its inception. Light-duty vehicles running on diesel will also have an impact.

Figure 6: Global oil-products demand for transportation (MM BPD)



Source: EIA, Arthur D. Little analysis

This brings up questions for each refining sector operator:

- Is there still a time window (i.e. 2025-2035) to get adequate returns on investing now in conversion upgrades for relatively small scale refineries?
- Which is the most cost efficient approach for adjusting production mix and getting fuels compliant with new specs?
- How to capture value from growing petrochemical business leveraging current refining facilities?

Petrochemical business impact

At some extent, EV penetration will increase the relative availability of naphtha from refineries as petchem feedstock. Geographies with structural low natural gas prices will experience a limited increase in penetration of naphtha as a feedstock, but in the end, it will depend on the Natural Gas-LPG-Naphtha volume equation. We expect relative lower prices for naphtha.

In any case, the most attractive economics currently come from integrated refinery and petrochemical complexes aiming to maximize petchem feed production at refineries. Hence, we expect most **new capacity additions to come in the form of "oil to chemicals".**

Fuel retail business impact

One factor challenging EV users is the availability of charging points other than at home. Consequently, we are seeing an increasing number of players investing in charging infrastructure. Many of these players are oil companies installing charging points at their gas stations, but others will include utilities and newcomers.

For oil (or energy) companies, the common business model is about lending a space to EV users for a limited time and charging cost plus tariff for the electricity, which is bought from the grid owner/operator.

Since the rest of the players are newcomers to the transportation business, it means we are already facing a paradigm shift. Oil companies are no longer the exclusive energy suppliers for on-road mobility.

We expect electricity distribution companies to make use of the capillarity from street lamp posts. Petrol stations at premium spots in cities will not be enough, and additional space for charging points will come from less costly and congested areas.

Fuel retail companies and independent dealers will push non-fuel business growth beyond its current share.

As a longer term challenge, fuel retailers will struggle to capture value from autonomous mobility.

This brings up questions related to the charging business:

- Will selling electricity make up for margin loss due to the decrease in fuel consumption?
- What is the best retail business model for oil companies regarding electricity penetration?
- Should oil companies partner with utilities or get their supply some other way, like producing their own?

How can Arthur D. Little support key players?

- Industrial reconfiguration design and feasibility
- Business model recommendations
- Segment and market-entry strategies
- Business and technology innovation
- Corporate venturing
- Fuel distribution and retail network strategy

Authors

Daniel Monzon, Carlo Stella, Mariano Aztiria

www.adl.com/Electric

Demystifying the charging challenge

A driver for convergence and new business opportunities

Alexander Krug, Andreas Schulze, Kai Karolin Hüppe, Johannes Herr

The combination of a growing need for electric vehicle charging and an energy industry increasingly reliant on renewable generation has led to many prophesizing power cuts and blackouts as current infrastructure struggles to cope. However, this charging challenge will instead open up new opportunities for the energy and automotive industries as the two converge. We explore how this will transform both sectors.

There is a widely held view that the combination of rising energy demand from electric vehicles (EVs) and the shift to fluctuating renewable power generation will lead to inevitable blackouts and power cuts. However, given the rapidly developing technologies and emerging business models in energy and mobility provision, how likely is this to happen in practice? In this article we provide an optimistic view of the future, in which we see the charging challenge as more of an opportunity than a threat for those mobility and energy players that can best exploit the new business prospects offered by the convergence of these two domains.

The charging challenge: Will EVs and renewables put energy grids under pressure?

In recent years, zero-emission transport and renewable energy have left their niches and become mainstream market drivers.

In 2017, we passed the first remarkable milestone in the EV market, when global EV sales passed the 1 million mark[1]. Since then the EV market has been gaining further momentum, driven by greater consumer acceptance, greater availability of infrastructure and favorable regulatory change. Countries across the world have set deadlines for ending sales of petroleum- and diesel-engine vehicles – for example, Norway in 2025, Sweden in 2030, and the UK, China and France in 2040. Consequently, automotive manufacturers have been focusing on a zero-emission future, boldly shifting investments towards vehicle electrification. Volkswagen Group, the world's largest automobile maker in terms of sales, plans to invest €44 billion by 2023 in electric vehicles and related digital services[2].

1. http://www.ev-volumes.com/news/global-plug-in-vehicle-sales-for-2017-final-results/
2. https://www.reuters.com/article/us-autoshow-detroit-volkswagen/volkswagen-to-invest-800-million-build-new-electric-vehicle-in-u-s-idUSKCN1P81R1

At the same time, renewables are becoming central to energy supply. Germany produced enough renewable energy in the first half of 2018 to power every household in the country for a year. In 2019, more than half of the UK's power has come from renewable sources. As of 2020, California will be the first US state to make solar panels on new buildings mandatory, which will support its goal to be CO2-neutral by 2045[3]. To meet climate change targets, legislators are looking to decrease harmful emissions from fossil fuel power generation, amid ambitious targets to reduce CO2 levels.

The automotive and energy industries have grown and developed independently of each other over the last decades. Each has faced its own separate opportunities and challenges. However, now, thanks to EV and renewables trends, they have begun to substantially affect each other. On the positive side, the electrification of cars and the shift from conventional to renewable energy generation have led to improved air quality by decreasing emissions. At the same time, they also put traditional energy networks under pressure – electric vehicles on the demand side and renewable energies on the supply side, as shown Figure 1.

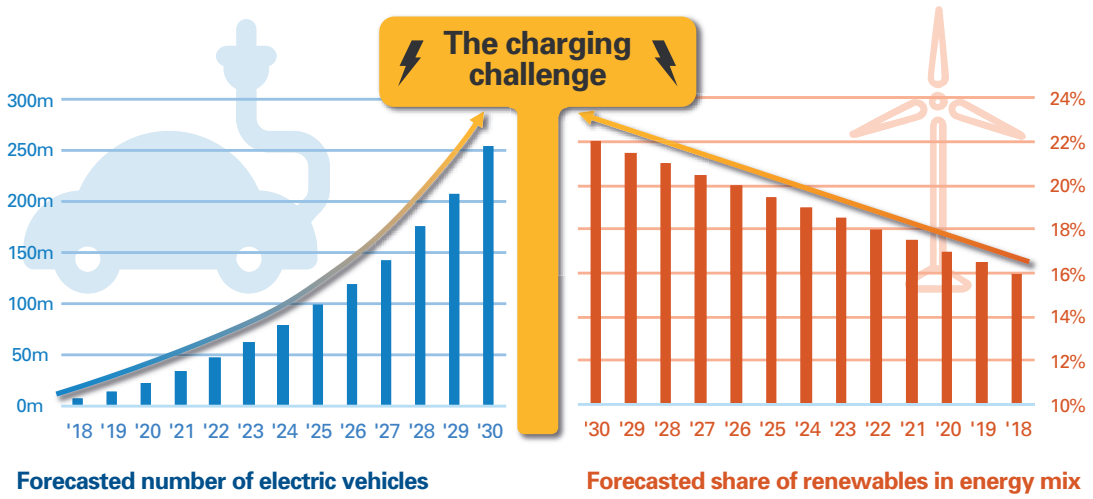


Figure 1: Global EV and renewables forecast until 2030: Pressure from the charging challenge[4]

Source: Arthur D. Little, IEA, DBS

3. https://www.erneuerbareenergien.de/archiv/kalifornien-fuehrt-solarpflicht-ein-150-436-108001.html
4. https://www.iea.org/publications/reports/globalevoutlook2019/, https://www.dbs.com/aics/pdfController.page?pdfpath=/content/article/pdf/AIO/082018/180820_insights_2030_energy_mix_marching_towards_a_cleaner_future.pdf

Increased volatility: Coping when the wind doesn't blow or the sun doesn't shine

Increasing energy generation from renewable sources threatens the stability of grids due to their time- and location-dependent availability. Wind is hardly predictable, and shows high fluctuations in power generation due to varying weather. Solar power may be more predictable, but is still volatile and only available during the daytime. It is also localized – in the case of Germany, most wind energy stems from the North of the country, while solar power is predominantly generated in Southern areas. Given that the German government has set a target of renewable energies meeting 65 percent of German power demand by 2030, this will lead to a supply-side challenge for electricity grids[5]. Similar grid challenges will arise in other countries, such as China, the world's biggest energy consumer. The government there has increased its original renewables target from 20 to 35 percent by 2030, which will lead to enormous expansion of fossil-free energy generation[6].

From a demand-side perspective, vehicle electrification will substantially increase electricity requirements. The combination of greater consumer acceptance, regulatory targets and more affordable vehicles will lead to growing market uptake, especially in Europe. From a cost perspective, by 2022 EVs will be on par with, or even drop below, the costs of internal combustion engine (ICE) vehicles in Europe, according to a recent study by Bloomberg New Energy Finance. This decrease in cost is mainly driven by the drop in battery prices. In just a few years this will make choosing an electric car over its ICE equivalent a matter of taste, not one of cost[7]. By 2040, 54 percent of new-car sales and 33 percent of the global car fleet are forecast to be electric, with China, the US and Europe making up over 60 percent of the global EV market[8]. Consequently, consumers' electricity demand will be significantly changed, in terms of not only electricity volume, but also charging power.

5. https://www.bmwi.de/Redaktion/DE/Dossier/erneuerbare-energien.html

6. https://www.bloomberg.com/news/articles/2018-09-26/china-sets-out-new-clean-energy-goals-penalties-in-revised-plan

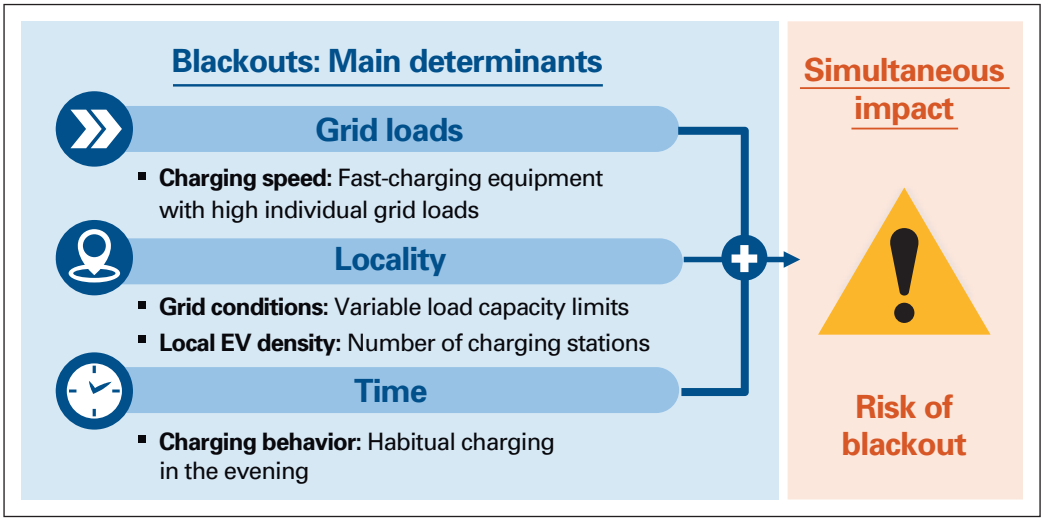
7. https://www.bloomberg.com/opinion/articles/2019-04-12/electric-vehicle-battery-shrinks-and-so-does-the-total-cost

8. https://data.bloomberglp.com/bnef/sites/14/2017/07/BNEF_EVO_2017_ExecutiveSummary.pdf

These two trends contribute to the same critical challenge – putting the electricity grid under pressure. They are often seen as leading to a potentially bleak outlook for maintaining a secure power supply.

The threat of electricity blackouts

So how real is the threat of local blackouts as energy networks are pushed beyond their maximum capacity? First of all, it is important to realize that this would not be a continuous problem: with EVs accounting for less than 10 percent of total electricity demand by 2030, the challenge is more around the time and local impact of charging. What happens if more fast chargers with higher load capacities are installed? What happens when every EV owner in a suburban residential neighborhood charges their vehicle at exactly the same time? Figure 2 illustrates the main determinants of potential blackouts: grid loads, locality and time.



Source: Arthur D. Little

Figure 2: Main determinants of potential blackouts: Grid loads, locality and time

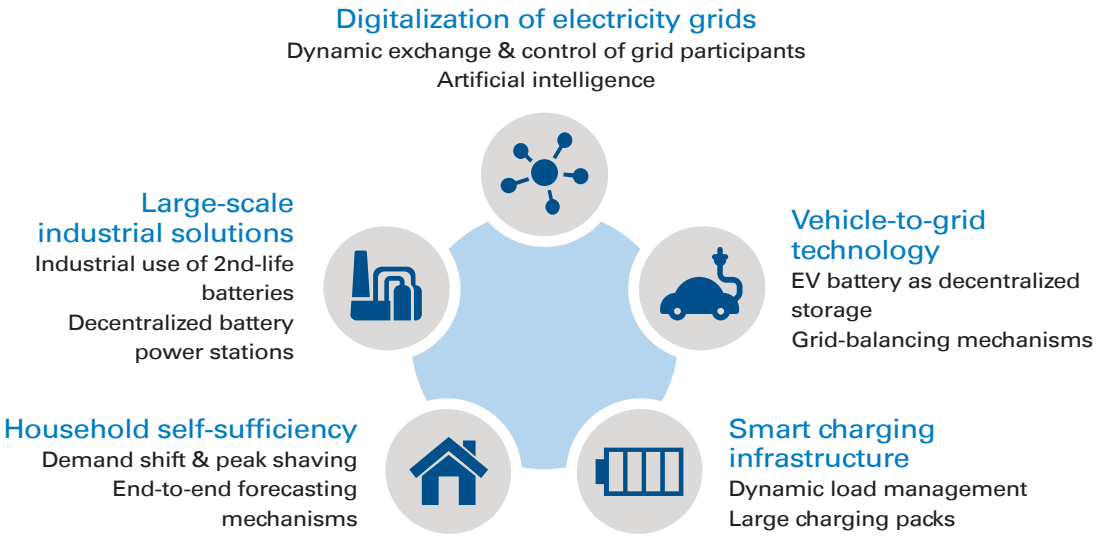
Many studies have discussed this threat and forecast nightmare scenarios that range from short-term local power outages to nationwide blackouts. The often-repeated message is that electricity grids cannot cope with forecasted vehicle electrification and renewable energy development at the same time. And it is very true that if grid infrastructure remains in its current state, blackouts and energy shortages will become a reality even before 2030.

However, in our analysis, this scenario will only be valid if energy and mobility providers follow the same patterns and business models that predominate today. In practice, we believe this is unlikely, as mobility and energy players have strong drivers to evolve their business models, and ample time to respond to the new opportunities afforded by technological convergence of electric vehicles and renewable energy applications.

Why the charging challenge will be overcome

The key reason for optimism is that all market players still have some time to adapt to changing requirements and transform their operations. EV penetration is an evolutionary, rather than revolutionary, process. Although electricity demand for charging EVs is expected to double by 2022, this still accounts for less than 1 percent of total electricity generation. Given that the major uptake of EVs, and therefore greater electricity demand, is only expected from 2025 onwards, providers have time to prepare.

Five key technologies and trends will support their transformation:



Source: Arthur D. Little

Figure 3: Key trends and technologies relevant for the charging challenge

1. Digitalization of electricity grids

Energy providers are increasingly investing in intelligent networks that will help to prevent grid instability and blackouts. Smart grids, which enable the exchange of information between different players within the network, are key to balancing electricity supply and demand. For example, the Trans-European Network for Energy facilitates transport of electricity over long distances across Europe, which lowers the risk of electricity blackouts. Current technology developments such as artificial intelligence, vehicle-to-grid/-home and dynamic load management will further support the development of intelligent and stable grids. Today, the building blocks for smart grids are already being put in place. In multiple countries, smart meters are becoming mandatory for businesses and end consumers with high electricity demand. In addition, electricity network providers are investing in intelligent transformer stations that contain metering and control functionalities. By making it possible to constantly monitor and steer voltage, current and frequency, these intelligent transformers also allow bidirectional flow of energy.

2. Vehicle-to-grid technology

Expensive infrastructure updates can be avoided with vehicle-to-grid technology that uses the batteries of EVs as a storage mechanism, which stabilizes the grid. If there is a surplus of electricity, EV batteries can be charged and serve as local storage. In case of electricity shortages, they can then feed energy into the grid or, alternatively, reduce their charging rates to keep the grid stable. The essential vehicle-to-grid technology to deliver these capabilities is still in its infancy and requires further development, but it is the focus of cross-sector research and studies that are building the pillars to exploit this new technology. Different players, including network operators, energy service providers and automobile manufacturers, are launching joint pilot projects. For example, Renault has begun piloting the first large-scale vehicle-to-grid charging project with electric vehicles in the Netherlands and Portugal. In the UK a consortium of players with different expertise, such as Nissan Motor Manufacturing UK, Energy Systems Catapult and National Grid ESO, are exploring both near-term and large-scale opportunities for vehicle-to-grid to play a role in a flexible energy system[9].

3. Smart charging infrastructure

The nightmare scenario of all EV owners plugging in their vehicles at once should be mitigated through the installation of smart charging infrastructure. Communication features and in-built load management will allow energy providers or charging infrastructure owners to flexibly control the charging process at one or more connected charge points, which will smooth electricity demand peaks. For example, even if every EV owner begins charging their vehicle at the same time every evening, the process doesn't need to be simultaneous. Dynamic load management enables the charging volumes to be distributed across the entire night, which will significantly reduce grid load.

Today, there is already a lot of smart charging infrastructure installed, which allows for communication and load management. In this major area of focus, we expect rapid maturing and expansion of more sophisticated load management systems, in both private and public charging infrastructure.

9. https://es.catapult.org.uk/wp-content/uploads/2019/06/V2GB-Public-Report.pdf

In addition to private households, larger energy consumers such as charging parks and other business facilities can benefit significantly from intelligent steering of charging processes, as it allows them to reduce demand peaks and thus avoid cost-intensive infrastructure expansion.

4. Household self-sufficiency

In 2018 there was a record number of installed photovoltaic (PV) solar panels combined with home battery storage, and this is predicted to grow in the future[10]. These households with battery storage have the potential to reduce grid loads and provide flexibility by shifting demand and lowering the need for electricity supply to their properties (and vehicles). Smart management of these electricity sources and consumer needs will provide an endless range of new applications and business models. For example, AI algorithms could evaluate driver profiles, weather forecasts and electricity consumption patterns to flexibly connect individual electricity sources to consumers, which will minimize energy cost, ensure high customer satisfaction, and limit the impact on local grids. In fact, home batteries are already being used to balance grid volatility due to the rise of renewable energy.

5. Large-scale industrial solutions

Advances in battery technology and rapidly decreasing kilowatt hour prices will provide larger-scale solutions to help with grid stability. Stand-alone battery power stations will be installed as significant local power resources, while smaller energy storage systems can ensure distribution grid stability. The growth in availability of dedicated power station batteries, as well as the increasing reuse of EV batteries, will feed this trend. For example, the second-life EV battery[11] market is expected to grow to $4.2 billion by 2025, with 70 percent of the market value originating in China and 16 percent in South Korea[12].

10. https://www.eupd-research.com/aktuelles/detail-ansicht/tesla-und-sonnen-als-mavericks-der-globalen-heimspeicherbranche/

11. Reuse applications for EV batteries after they are no longer fit to their original purpose (e.g., in stationary storage systems)

12. https://www.pv-magazine.com/2018/08/03/second-life-ev-battery-market-to-grow-to-4-2-billion-by-2025/

Audi has recently installed stationary energy storage with capacity of 1.9 MWh in Berlin. Fortum, as well, is piloting different second-life battery solutions, testing new business models. In India, for example, Fortum is developing a leasing model in which auto rickshaw owners can give back their used batteries for recharging and receive full batteries in return[13].

Taking them together, we expect these trends to enable grids to cope with the charging challenge despite rising vehicle electrification and renewable energy use. Batteries and smart charging infrastructure will provide **flexibility**, while intelligent networks and connectivity allow for **decentralized energy management**. Finally, **monetary incentives** across all applications will ensure market attractiveness. Some utilities have already started to introduce such tariffs, especially for B2B customers, while reduced grid connection costs for interruptible consumers such as EVs allow for short power cuts in case of grid instability.

Both utilities and e-mobility providers have explicit interest in supporting these developments, to prevent unnecessary costs for grid extensions and ensure a flawless customer experience for EV users. Other players, too, are entering the market; often these are mobility service providers emerging from the start-up landscape with strong digital focus. In these rapidly converging industries, we expect a new competitive landscape to quickly develop on the base of new business models.

13. https://www.fortum.com/second-life-lithium-ion-batteries

Incumbents, challengers and new business models – Which will win the battle?

Potential new business models will arise from the charging challenge, for both established energy market incumbents and challengers such as automotive manufacturers and mobility service providers. Energy companies will heavily invest in public charging infrastructure to provide viable alternatives to home charging, while e-mobility players extend their offerings to support grid-stabilizing mechanisms. Each of these players brings different core competencies to the table:

- Automotive manufacturers have global retail and brand experience at their disposal.
- Energy incumbents build on vast energy technology and regulatory expertise.
- Smaller mobility players are able to take on specific niches at high speed and with advanced digital skill sets.

When it comes to successfully introducing new business models, all these strengths can be crucial. Which players will emerge as the winners? Three aspects are likely to be important: margins, customer access and technological capabilities.

- **Automotive manufacturers**, with well-established B2C and B2B customer bases, as well as command of vehicles, will enter the charging challenge from a position of strength and are likely to have the initial advantage in generating enough margins. Clearly, their products are focused on the vehicle, with little or no reach into customers' households. They do, however, hold the advantage in terms of their experience in emotionally charging products and building brands. We therefore expect manufacturers to extend their offerings towards the "energy solutions" business by making use of their EVs, brands, and market access. For example, Volkswagen Group founded Elli, an energy and charging solutions provider, in 2018. Elli aims to offer a seamless and holistic energy and charging experience for electric car drivers and fleet managers.

- **Energy incumbents** have a greater challenge due to their traditional focus on energy provision as asset-heavy and cost-driven Enterprises. However, those players that are able to move away from central generation, transform their infrastructure, digitalize their businesses and refocus on the consumer[14] have good chances of success. This trend is already well under way, as shown by, for example, the splitting of E.ON into E.ON and Uniper, and RWE into RWE and Innogy. Continuous investment from Engie in customer energy management and demand response players is another example. Smart home appliances allow energy players to gain access to customers' homes. They can also use their independence from automotive brands as a unique selling point, especially with corporate customers. In addition, existing energy players will have networks of installers, which will provide an advantage when it comes to deploying relevant hardware.

- **New challengers**, such as mobility and energy service providers, pose a serious challenge, given their speed, strong focus on the customer, and digital capabilities. While many corporates make use of internal incubators to create these capabilities, start-ups with technology focus are likely acquisition targets. For example, Shell has been investing heavily in energy and mobility service start-ups such as Sonnen and NewMotion. Amazon is leading a $700 million round of investment in Rivian, a potential rival to EV manufacturer Tesla, as well as investing heavily in customer energy management providers[15]. Well-known automotive players, similarly, are investing in high-potential e-mobility companies such as Rimac. This Croatian company develops EVs with advanced battery and control technology, and was able to attract investments from Porsche, Hyundai and Kia[16]. These challengers will address specific "high value" spots in the value chain where they are likely to have the upper hand over the industry giants, at least initially.

14. See also companion article "Getting ready for the energy consumer of the future" elsewhere in this issue of Prism
15. https://www.handelsblatt.com/unternehmen/industrie/investment-in-rivian-amazons-700-millionen-dollar-wette-auf-elektroautos/23993148.html?ticket=ST-4042233-xkh9h2mcV4engxygsNW4-ap2
16. https://cleantechnica.com/2019/05/15/hyundai-kia-make-an-80-million-euro-investment-in-rimac/

Figure 4 summarizes the positioning of players entering the charging challenge and opportunities for new business models.

New business models: Winning the battle

	Key challenges	Opportunities
Automotive manufacturers	▪ Non-core technological background ▪ Low bargaining power in established energy business	▪ Diversify into energy solutions ▪ Exploit strong customer base ▪ Leverage product development competencies
Energy incumbents	▪ Inert due to asset intensity – limited chances without divestments ▪ Lack of direct and emotional customer relationship	▪ Prepare for radical transformation ▪ Invest in home energy management ▪ Exploit technological competency, digitalization & market independence
New challengers	▪ High barriers to entry due to limited customer access and regulations ▪ Low bargaining power in established energy business	▪ Focus on high-value market niches ▪ Leverage own dynamics to exploit inertia of established players

Source: Arthur D. Little

Figure 4: Charging challenge business models: Opportunities and challenges

Insight for the executive

The competition has begun around future energy business models. The charging challenge is unlikely to lead to blackouts or instability, given the strong drivers for new business models, the potential of converging technologies, and the availability of sufficient time for key players to adapt. On the contrary, the rise of EVs will very much prove to be an opportunity. In converging industries, the charging challenge will enable new business models, which will see established and new players competing. We expect energy and automotive incumbents, as well as new challengers – often smaller mobility players and energy service providers – to open up these new areas.

Today, these players start from different positions with their individual sets of capabilities. With smaller players as likely acquisition targets, both of the giant industry environments of energy and mobility promise to drive consolidation as

competencies converge. This can be seen in the automotive industry, as alliances have become increasingly popular to fund the significant investments required for new e-mobility capabilities. In the meantime, energy players themselves have been consolidating, and will be further driven to demerge asset-heavy and cost-intensive electricity generation businesses.

Realizing margins within these new business models is based heavily on gaining substantial market shares, which means we expect a "volume-driven game" to emerge in these areas. Currently, automotive manufacturers seem best equipped to succeed in this competition, but the challenge requires all players to change and adapt if they are to drive long-term success.

Upscaling digital pilots in oil and gas

How are oil and gas companies adopting digital in their operations, and how can they shift from pilots to full-scale implementation?

The oil and gas sector has been applying cutting-edge technologies and digital solutions for years but failed to tap the full potential of digital. Companies have been able to sustain these inefficiencies during the period of high oil prices. However, with the increasing market pressures, they must better utilize the available digital applications to remain competitive. Moreover, the COVID-19 crisis is changing the sector, with oil prices plummeting to lows not seen since 1998, forcing oil and gas companies to further accelerate the incorporation of digital solutions.

The oil and gas sector amid the second digital wave: key digital applications and benefits

In the 1990s, the first digital wave started in oil and gas, with companies adopting pilots of digital oilfield projects aimed at leveraging data for real-time monitoring and decision-making. However, terabytes of data were generated by each drilling rig per day, but just a fraction of this information was used for the decision-making. Such inefficiencies have not been possible since the fall in oil prices in 2015.

In the last few years, the oil and gas sector has been going through a difficult period, with a decrease in demand, low oil prices (for longer), and increasing regulatory pressure. It has also faced increased cyber-attacks threatening assets and information. Companies had to reduce costs, improve efficiency and cyber resilience, and maintain margins in order to sustain the difficulties in this sector. Among multiple initiatives, these companies have embarked on the second wave of digital transformation, hoping to stay competitive and improve operations.

Around 10–20 percent of oil and gas industry processes are currently digitized, and a significant increase in digital adoption is expected in the next decade, with approximately 30 R&D programs on "digital oil fields" currently being run by more than 10 leading international companies.[1] Artificial intelligence, machine learning and data analytics, represent the three major digital applications that have been adopted by leading oil and gas companies. Below, we showcase the digital experiences of four national and international oil companies:

Equinor's digital applications (Norway): Equinor's strategy emphasizes innovation and digitalization, and the company has been adopting digital applications in its operations for many years. In 2018, Equinor launched the first-ever fully automated, unmanned, remotely operated platform, Oseberg H. The pilot was delivered with more than 20 percent cost reduction compared to the plan, as well as a breakeven price reduction from US$34 to less than US$20 per barrel. [2]

Shell's digital applications (the Netherlands/global): Shell holds a decade of experience in worldwide smart-field applications, which has enhanced its returns from production by approximately US$5 billion over five years due to digitization of roughly 50 assets. In addition, Shell achieved 50 percent reduction in electrical submersible pump start-up time after trips to Siberia, and 20 percent reduction in travel time to remote assets in the Middle East from numerous smart field applications.[3]

ADNOC's digital applications (UAE): ADNOC recently launched its 2030 Smart Growth Master Plan to optimize production and achieve gas self-sufficiency, implemented predictive maintenance for 2,500 pieces of rotating equipment through machine learning and AI, and applied blockchain for better transparency in trading and accounting.[4] Moreover, the ultra-sour Ghasha field project is expected to start soon, focusing on digital with smart workers, automation, robots and

1 Bloomberg Professional services (2019)

2 Equinor (2018). ***Production start at Oseberg Vestflanken 2***

3 Chai, C., Van Den Berg, F., P., E., & Shell Global Solutions International B.V. (2015). ***Smart Fields: People, Processes and Technology***

4 Society of Petroleum Engineers (2019). ***ADNOC, Honeywell Team on Large-Scale Predictive Maintenance Project***

drones for remote maintenance and surveillance. The project will be managed and operated from a centralized control and monitoring center.

KOC digital applications (Kuwait): Kuwait Oil Company has three major digital projects across its assets (North Kuwait, West Kuwait, and South & East Kuwait), which are still at the pilot phase as part of the Kuwait Integrated Digital Field (KwIDF) program.[1] The aim of this program is to have real-time surveillance of wells and promote collaboration and integration between surface and subsurface groups and teams across KOC. The program also accelerates the data-to-decisions cycle at all levels of the company's organization through integration of production data and workflows.

Digital applications' benefits: Incorporating digital applications into the oil and gas sector can lead to multiple benefits:[2]

- Approximately 10 percent increase in production volumes.
- Roughly 1–3 percent reduction in CAPEX for oil and gas projects.
- Around 2–5 percent reduction in OPEX.
- Approximately 5–10 percent reduction in maintenance, repair, and operations inventory (MRO) through real-time tracking and monitoring of inventory and supply chain.

However, oil and gas companies are still facing multiple challenges in adopting and unlocking the full benefits of digital and are still not able to upscale their digital applications.

Key challenges in shifting from pilot to a full-scale digital transformation

Based on our strong experience and engagements with oil and gas technology and digital transformation projects, as well as interviews with top global digital oil and gas advisors to help NOCs and IOCs upscale digital transformations, we have identified multiple challenges in applying digital to operations:

Major challenges faced in upscaling digital pilots

Source: Arthur D. Little analysis

1. Limited support from top leadership for digital rollout: Digital adoption requires a fundamental shift in how work gets done and, most importantly, how decisions are made at leadership level. The majority of leadership teams in oil and gas companies believe digital transformation is the responsibility of the chief information officer and do not believe that every leader should assume an active role of change manager within their department.

2. Limited leadership awareness of digital applications' benefits: Leadership has so far struggled to see the benefits of applying digital technologies to the oil and gas value chain due to lack of knowledge and unawareness of the ample applications and uses of digital.

3. Dominance of silos: Top management, unit leaders and heads of departments have always been used to working in silos, setting goals and plans for their own units and departments and never having the urge to collaborate across units or departments. This has encouraged employees to adopt cultures that do not promote technology transfer. Digital transformations, on the contrary, require collaboration and integration across departments for data sharing and analysis, which leads to dismantling of organizational silos. Similarly, in the oil and gas industry as a whole, companies are operating in silos and competing against each other to win the digital race.

4. Lack of holistic and well-defined transformation program: Driving a digital transformation requires a wide-scale progressive effort, which could be challenging to execute. Staff compliance, cultural shifts, people management and utilization, and modifications to systems, processes, and organizations are required. All these changes entail a well-defined transformation approach with dedicated change agents leading the move.

5. Employee resistance to change: Oil and gas employees fear losing their jobs and experiencing sudden changes in their usual ways of working. Technical oil and gas employees also worry about their skills becoming obsolete, and that more work will be required from them to adapt to the new changes, especially when it comes to data-analytics capabilities, which they often lack. Moreover, approximately 27 percent of the workforce in oil and gas is above the age of 55 and might express skepticism about whether introduction of digital applications is required at this stage of their careers.[3]

6. Lack of people management and utilization: Employees will be concerned about their jobs and uncertain about the future ways of working. In addition, firing employees due to automation may not always be possible, especially with employees' higher awareness of their rights and global dominance of national oil companies (NOCs) with the need to balance generating earnings for their countries and employing nationals.

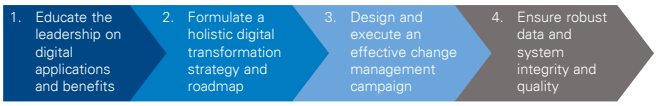
3 Kennedy, K., & Vanessa, G. (2016). ***Preparing for an Aging Workforce: Oil, Gas and Mining Industry Toolkit for HR Professionals***. Society for Human Resource Management

7. Difficulties amending the organization's structure, processes and procedures: Oil and gas companies are facing further difficulties in implementing changes within the organization structure, processes, procedures and interactions with operational partners, especially in JVs, as they require time, support and buy-in across their organizations and breaking organizational silos. Some companies are managing the digital transformation with "design digital teams" at the headquarters, and newly hired data scientists and experts, as well as "implementation digital teams" composed of operational employees, at the assets. However, these "parallel structures" could create additional silos and barriers in the organization if either asset's end-user engagement is late or digital applications designed at the headquarters do not always incorporate end users' input; this would lead to resistance from asset teams to adopting the application.

8. Lack of a holistic transformation strategy and master plan: Oil and gas companies' management teams are not developing holistic digital transformation roadmaps and strategies that cut across teams and disjointed pilots. The absence of a holistic digital roadmap, coupled with lack of proper management of digital and technology portfolios, has resulted in several irrational digital investments and initiatives across the sector. This has been especially impactful with the unavailability of a proper financial assessment of solutions in terms of compliance with international norms, rules and standards. Companies have mostly adopted innovation on a small scale, with strategies and plans set for separate pilots, which has led teams and units to keep operating in silos.

9. Skepticism of data and system integrity: Some leaders and employees have questioned input data quality, the integrity of data handling and integration from different departments, and the outcome from visualization centers and dashboards. The limited trust in the outcome has led some employees to maintain their old ways of working through standard and basic models and spreadsheets.

Steps to resolve challenges in upscaling digital pilots



Source: Arthur D. Little analysis

Key solutions for oil and gas companies to upscale their digital transformations

1. Educate leadership on digital: Leaders are responsible for setting a clear path for digital transformation and must implement the change. They should shift their mind-sets to realize that the sector is changing, and digital transformation is not the role of the CIO only. Leaders should not only raise awareness and promote digital shift, but also adopt digital in their day-to-day activities.

Leaders should be well educated about the available digital applications in the market, their benefits, and the added value they bring to the organization from cost savings and increases in efficiency. Moreover, they should also learn from other industries such as telecom, healthcare, and aerospace about the benefits captured by first adopters of digital and the tremendous losses faced by laggards.

2. Formulate a holistic digital transformation strategy and master plan: These should link all internal digital programs and mega-projects based on business needs. All existing digital initiatives, lessons learned from these initiatives, and capabilities within the company should be mapped and included in the master plan as part of a holistic digital portfolio, with digital initiatives organized and prioritized based on their added value and financial feasibility. Furthermore, the master plan should include clear KPIs for digital transformation implementation for all relevant stakeholders to ensure accountability and timely delivery of initiatives.

3. Design and execute an effective change management and communication campaign: The change management campaign should be aligned with the overall company digital masterplan and led by the leadership, who should play the role of change champions. They should communicate the transformation plan, ambitions, and benefits to employees and get support from experts in oil and gas digital to transfer technical know-how to the organization.

The organization structure and processes should also be revised to incorporate digital changes without creating "parallel structures" within the organization. Data scientists and engineers should be collocated at the assets to ensure a collaborative and effective design to the implementation process.

4. Ensure robust data and system integrity and quality: Robust data and system architecture should be put in place to ensure the quality of the digital platform outcome is good and, consequently, secure end users' trust. To achieve a robust architecture, companies should have multiple trials and simulations on the system, better structure, and integration of real-time data from different departments, and effectively manage large analytical models.

How can Arthur D. Little (ADL) support leading oil and gas companies in their digital transformations?

Since the 1960s, Arthur D. Little has been the agenda shaper of the oil and gas sector, particularly due to setting up multiple NOCs and supporting them in their transformations. Our historical relationship with leading oil and gas companies puts us in a great position to shape the future of oil companies, especially to support them in their digital transformations through:

Strategy and master plan development: Develop your holistic digital strategy and master plan, linking all your existing and future digital initiatives.

Change management design and execution: Develop and support your company in executing your change management plan through our "ADL Scale-up Engine" to move from pilots to full scale. This approach will include quantification of benefits realized, communication of benefits to the entire organization to increase acceptance and adoption, and communication of best practices from digital applications at other companies (oil and gas and other sectors) to increase your company's know-how in digital.

Digital processes and organization assessment and design: Review and revise your processes and organization structure to put them in line with your digital strategy.

Post-execution digital health checks: Conduct regular health checks after execution of digital projects, based on 10 key dimensions, as part of our "*Digital Shift Health Check*".

Case study: Digital oil field pilot… from success to significance!

We ran a four-year digital upscaling pilot program with more than 150 wells networked on one of the largest producing fields in the world. The latter was struggling from constrained production, which had resulted from limited wet crude oil-handling capacity, lack of accurate well integrity performance, and uncertain subsurface reservoir characteristics.

Our major objectives relied on:

- Optimizing production by identifying water encroachment in wells and enabling the company to react and control.
- Optimizing capacity by enhancing current and future production capacity to provide a sustainable oil rate.
- Data collaboration by improving data integrity, visibility, communication and knowledge sharing.

We consequently implemented our digital transformation framework, the "*ADL Scale-up Engine*", which focused on upscaling operations. It included both intelligent fields with smart monitoring systems, real-time data and solar panel-powered systems, digital controls with a collaboration center (covering operations, drilling and subsurface), daily production optimization, life-of-well information, a production-monitoring system, and easy and smart visualization tools.

Our pilot program has succeeded in creating integrated decisions and delivering one upscaled and connected system of intelligent operations and asset management, collaborative workforce and digital supply chain.

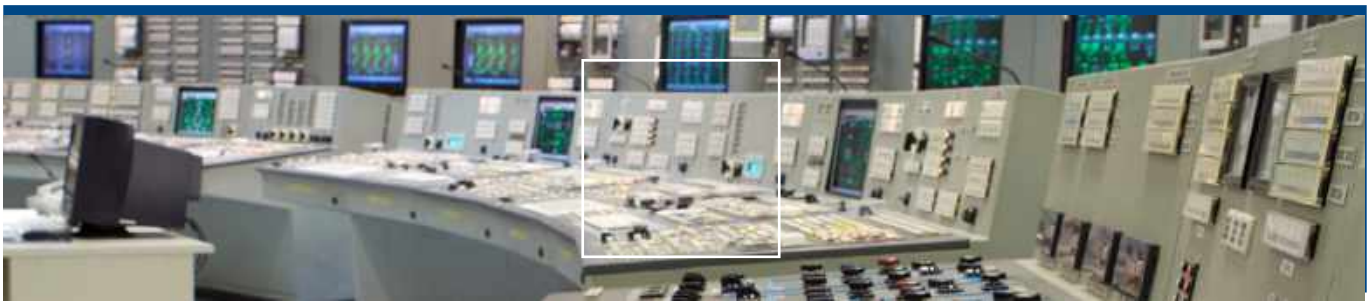
Authors

Adnan Merhaba, Amer Hage Chahine, and Theresa Karam

www.adl.com/UpscalingDigitalPilots

Nuclear lean

Combining safety culture and operational excellence



Nuclear power plant owners are hesitant to pursue life extension projects, and in some cases, are even shutting down their plants. As plants age and safety requirements inflate costs of life extension projects, nuclear plant owners often do not find these projects an attractive business case. This, combined with lack of political support, fear of national nuclear phase-outs, and competition from other (often renewable) energy sources, has forced the premature shutdown of several nuclear plants across the world. Arthur D. Little's industry insight confirms that nuclear power plants run safely under normal circumstances, but don't generally operate at their technical and economic optimum. To regain profitability and deliver the nuclear promise of a safe, reliable and economically convenient energy supply, the nuclear industry must improve. We believe a lean management framework to nuclear operations ("Nuclear Lean") can bring significant performance improvements and cost reduction beyond 15 percent. This will help nuclear energy to stand its ground in the energy ecosystem of the future.

Nuclear energy is struggling as the energy market changes

The nuclear industry is at a turning point: as the energy markets embrace decentralization with renewable energies and cheap fossil fuels, nuclear is struggling to stay in the picture. Since 2013, in the United States alone, eight nuclear power plants have been shut down before their designed end of life. With them, approximately 6 GWe of baseload capacity were lost. This prevented the production of more than 20 million CO_2 tons per year. Likewise, Germany and Belgium have decided to phase out their entire nuclear fleets by the mid-2020s.

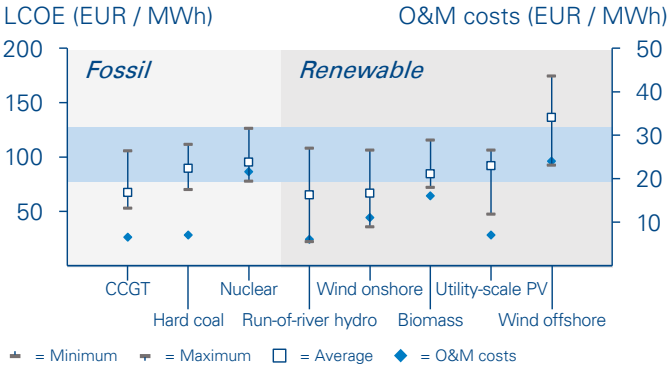
Premature shutdowns are symptoms of an industry-wide trend with a variety of triggers. Below are three examples:

Lack of political backing: Because politics and the public in general are empowering renewables, nuclear power plants must be prepared for national phase-outs.

Limited economic competitiveness: With low carbon prices, nuclear has a higher levelized cost of energy compared to other thermal generation sources despite its positive impact on carbon emissions. (See below figure.) In addition, renewables benefit from subsidies and their technology prices are decreasing.

These factors have resulted in a difficult position for nuclear within the generation portfolio.

Levelized cost of electricity (LCOE) and operations & maintenance (O&M) costs for different energy sources



Source: Arthur D. Little analysis

Increasing safety requirements: Safety requirements imposed by national safety authorities are getting more demanding, and this is making it difficult for nuclear operators to justify the lifetime extension business case. This situation is often emphasized by issues with the aging workforce, which limits suppliers' ability to deliver capital projects on time and on budget.

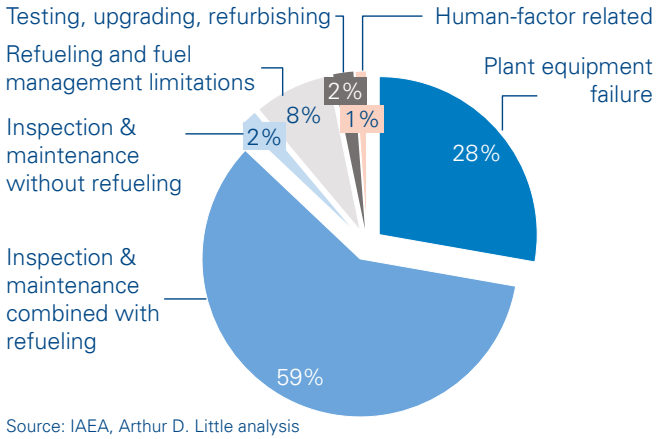
This lack of attractiveness to decision-makers will lead to shrinkage of nuclear in the global energy portfolio in the next years, despite aggressive new building in China and other emerging countries.

To counter these trends, the nuclear industry is already making industry-wide efforts, e.g., through the Nuclear Energy Institute's (NEI's) strategic plan, "Delivering the Nuclear Promise©", and its efficiency improvement bulletins. Another example comes from productivity and optimization solutions developed by various players in the nuclear industry, e.g., Bruce Power's Asset Performance Management (APM) system. However, these measures do not yet unlock the full cost-saving potential that has been observed recently in other high-reliability organizations, such as airlines, hospitals and semiconductors.

Efficiency potential in nuclear operations

The average energy availability factor (EAF) for nuclear power plants worldwide in 2015–2017 amounted to 82.2 percent (excluding the idle Japanese fleet). This includes a tail of poorly operating plants, whose EAFs can drop to under 70 percent. Arthur D. Little's research on top-performing nuclear power plants shows significant room for efficiency improvement: best-in-class benchmarks can be found, e.g., in the US plant Dresden 3 and the Finnish plant Loviisa 1, whose EAFs reached 100 and 92.7 percent, respectively, in 2017. Likewise, the German Isar 2 plant has been among the world's top 10 nuclear power plants several times, with more than 95 percent EAF.

Internally triggered full outage downtime by major cause (as percentages of the total) for the French and German operational nuclear power plant fleets



Source: IAEA, Arthur D. Little analysis

The above figure shows plant equipment failure and inspection & maintenance, combined with refueling, which represent more than 80 percent of nuclear plants' internally triggered downtime. Both outage types involve complex processes concerning several activities and departments. Task management is complex and inefficiency may result.

However, in stark contrast an EAF close to 100 is possible even in older facilities, as benchmarks such as Dresden 3 show.

Arthur D. Little research shows that internally triggered downtimes beyond technical constraints often originate from how the plant is managed and what performance culture exists beyond safety. This is well in line with other industry examples, and leads to substantial cost-saving potential that usually does not collide with safety constraints.

Lean management in safety-driven industries

Lean is a leadership and organizational concept to systematically avoid waste, failures and unnecessary cost. Originally having evolved in automotive manufacturing, it became a general leadership approach for any kind of operational and administrative business process, and is now often labeled "lean management". It has focused on creating value and establishing a "zero-failure" philosophy, while avoiding redundancy by optimizing alignment of activities. Because of this, lean management has generated increasing awareness in safety-driven industries in the last years (e.g., the process industry, aviation and healthcare). Observed lean activities have led to substantial downtime reductions, which has brought plant performances up to levels of best-in-class plants (more than 90 percent. These practices have also achieved significant cost savings (frequently exceeding 15 percent), shorter lead times, and increased process compliance.

Arthur D. Little's Nuclear Lean framework focuses on performance improvement in nuclear operations, respecting the necessary safety principles and general safety culture requirements. Our approach combines performance improvement with long-term leadership and capability building to meet competitive energy market challenges. Compared to traditional, and often failed, method-based lean concepts, our framework strives to build sustainable lean governance.

Closing the efficiency gap

Nuclear benchmark plants improve their performances by continuously synchronizing their nuclear operations processes and professionalizing their failure prevention routines.

End-to-end process management

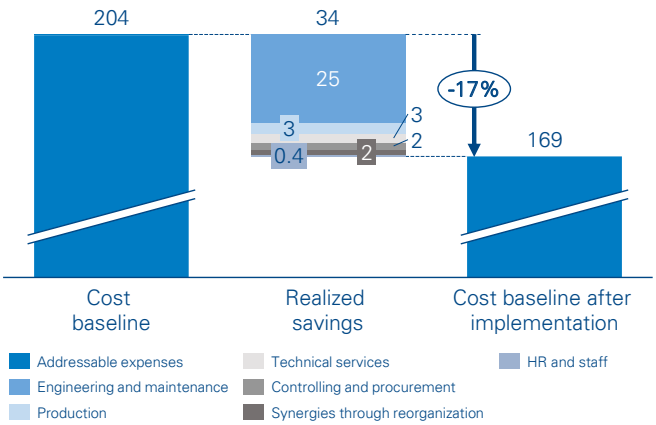
Minimizing idle capacities in plant operations promises efficient, reliable plans and schedules for inspection and maintenance. They need to be designed with a holistic approach, integrating processes from planning and scheduling (work management, materials services) to execution (plant operations).

Process optimization efforts should focus on reducing the overall lead time by eliminating non-critical idle time. New efficiency potential can be realized through end-to-end process

harmonization (e.g., plant outage due to corrective maintenance of failed equipment). This overcomes cross-functional and cross-organizational silos with management supervision and end-to-end key performance indicators (KPIs). To achieve this, role definition and implementation of "process management" to monitor and steer process performance improvement is fundamental.

Arthur D. Little has exhaustive experience in the nuclear industry, as we have already addressed the application of lean management concepts to nuclear plants. For instance, we applied these concepts in a performance improvement project for a German nuclear plant operator. During the project, Arthur D. Little restructured the client organization according to lean principles, moving from a systems-oriented organization with departments such as "mechanical maintenance" and "electrical maintenance" to a new structure that encompassed end-to-end processes. This new organization followed the logic of end-to-end processes such as "production", "technology" (covering, e.g., engineering and maintenance), "technical services" (covering, e.g., radiation protection) and "commercial services". This helped the client to reengineer its business processes and identify 34 EUR mn in waste, namely, 17 percent of total addressable costs, which were sustainably saved. (See below figure.)

Effects of nuclear lean in a German nuclear plant (EUR mn)



Source: Arthur D. Little analysis

Problem-solving: Root-cause analysis and optimization

Reducing plant equipment failures and outage time requires a continuous process of problem solving. As effect and root-cause are often detached by a temporal and organizational gap, the problem-solving process should bring involved functions and organizational departments together.

A main responsibility of the project manager is systematic root-cause analysis and optimization implementation. Root-cause analysis should be applied beyond technological aspects to address process inefficiencies and identify optimization opportunities. An example is the total outage downtime for maintenance and repair, combined with refueling. Tools such as fishbone analysis and best-in-class benchmarking can identify root-causes forcing downtime overextensions (e.g., inspections that can be executed in service, poor planning and problem anticipation attitudes). Efficiency can increase through identified improvement measures, and ad hoc established KPIs (e.g., total downtime extension caused by poor planning) can monitor the results.

Implementing continuous improvement

Nuclear benchmark plants are driven by a mind-set of continuous improvement, which fits very well with the lean management approach. From our perspective, a viable nuclear lean organization is built on three pillars:

1. Leadership, to clearly formulate expectations and help introduce an effective management and delegation culture, which will lead to continuous improvement.
2. Target establishment, to define concrete objectives in the performance of the end-to-end processes and monitor it through tailored KPIs, which will assure the effectiveness of the introduced measures (e.g., average downtime).
3. Use of continuous improvement ("Kaizen") platforms, to set up a culture of perpetual improvements through small optimization steps and address the right problem with the right set of employees.

Nuclear power plants will achieve sustainable improvements in process times and compliance through application of all elements of our nuclear lean framework. This will lead to savings in operations and maintenance costs.

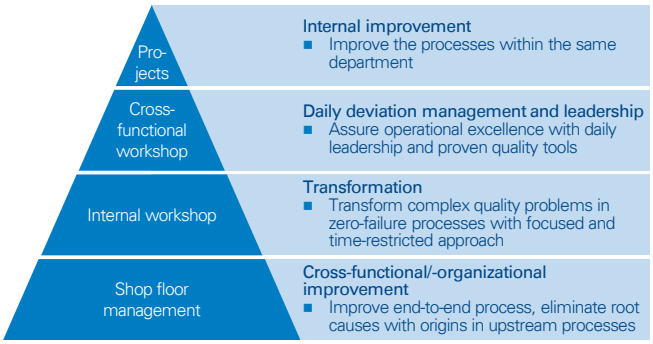
Continuous improvement: "Kaizen platforms"

Depending on the individual improvement needs of the nuclear operation, there are different options for improving its current state. The right Kaizen platform is selected according to the size and importance of the efficiency gap. Although daily routines can address smaller improvement needs while following a sustainable continuous improvement approach, larger issues need to be delegated, for example, to dedicated teams. Establishing continuous improvement as a daily routine not only leads to involvement of the entire plant's workforce, but also ensures that the changes will be sustainable. However, integration of continuous improvement into work routines is limited to smaller issues. Complex topics must be delegated to assigned work groups and followed up accordingly. An example is very small improvement tasks resolved in daily shop-floor management, versus scheduling optimization designed in cross-functional, end-to-end process workshops. (See figure the on the next page.)

The following aspects need to be emphasized:

- Daily performance management needs to be established based on forward-looking steering KPIs.
- Daily performance dialogues must become the main platform for daily deviation management. If possible, measures for problem solving should be defined here.
- Standardized, end-to-end-workshops should become the main cross-functional performance improvement platform.

Kaizen platforms in nuclear operations



Source: Arthur D. Little analysis

Developing the Nuclear Lean capability

Developing the required capability and establishing the necessary management system throughout the organization remains a top-management issue. It must ensure commitment and communication to "live lean" and ensure cultural change. This is achieved through process-oriented, cross-functional workshops, continuous improvement via Kaizen platforms, and root-cause elimination. Top management must, however, be aware of cultural challenges in the implementation of a new management system in a routine-based environment. It must also be ready to promote comprehensive workforce involvement. Numerous projects show that top-management awareness of lean management and its holistic implementation remain one of the most crucial success factors regarding achievable performance improvements.

Conclusion

Safety targets and standardized procedures are clearly defined and usually obeyed carefully within nuclear power plant operations (e.g., EUCG's Standard Nuclear Performance Model). Nevertheless, targeting specific processes within routine operations by applying lean management can lead to significant availability increases and, subsequently, lower operating costs. At the same time, the company does not have to sacrifice safety or sustainability.

Arthur D. Little's Nuclear Lean framework provides a holistic approach, which focuses on sustainable performance improvement in safety-driven environments through its zero-failure philosophy principle.

The operational core of Nuclear Lean focuses on end-to-end optimization of nuclear operations and cross-functional problem solving. This operational core is embedded in a holistic concept, in which performance improvement is realized in Kaizen platforms for continuous improvement.

Authors

Tommaso Sacco, Michael Kruse, Bernd Schreiber, Kai-Oliver Zander

www.adl.com/NuclearLean

Flexibility services: Catch me if you can!

Why and how utilities should seize the opportunity before others do

As utilities are exposed to bigger risks of supply-and-demand imbalance fueled by unpredictable, intermittent generation sources, they are searching for flexibility solutions to offset their open positions. In this market context, energy aggregators have emerged, and are taking an increasingly important role in optimizing electricity generation and demand volatility by providing the needed flexibility. Meanwhile, multiple traditional (integrated) utilities have developed similar demand-side response (DSR) solutions and even acquired aggregators altogether. Catching the inherent value in these services is becoming part of the core business of utilities. However, being in this game requires speed, skills, agility and differentiators. The key question is how utilities can make this happen.

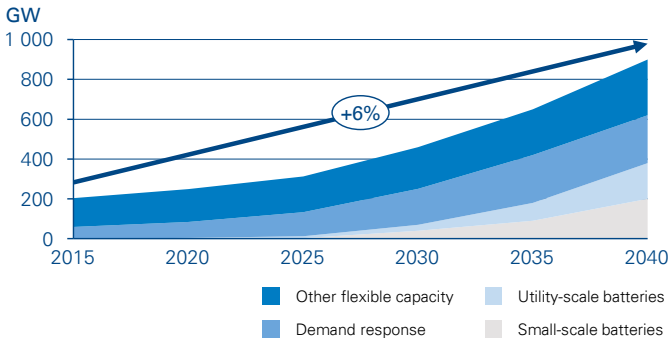
While it could seem counterintuitive at first, multiple factors are pushing utilities to become active providers of flexibility services, which is outside of the traditional comfort zone of the energy commodity. We distinguish three main reasons traditional utilities are adding flexibility services to their commercial offerings.

Benefit 1: Additional source of stable revenues within the rapidly growing flexible-capacity market

Underlying market drivers for flexibility (the rise of intermittent generation, the expected shutdown of conventional generation assets) are gaining strength. Consequently, the global market for flexible capacity is expected to experience significant growth, at a CAGR of 6 percent over the next two decades, to reach 900 GW by 2040. However, there are important differences in the forecasted growth rates of the different types of flexible capacity under consideration.

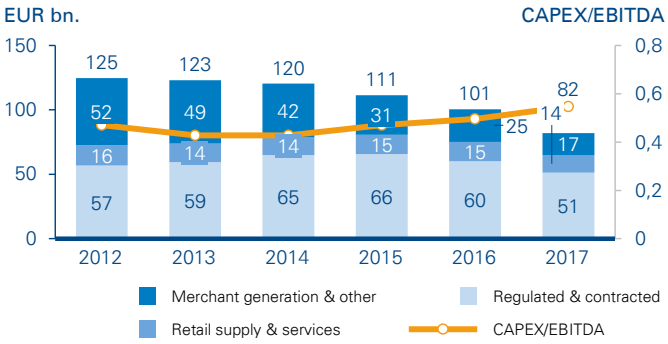
First, the share of DSR within the flexible capacity mix is expected to remain stable at ≈27 percent. Second, the share of utility-scale and small-scale batteries is expected to grow at a CAGR of ≈23 percent, resulting in a combined share of ≈42 percent of the total flexible capacity in 2040. Finally, the relative share of other flexible resources, such as open-cycle gas plants and gas peakers, is expected to drop from ≈71 percent in 2015 to ≈31 percent in 2040, at a lower-than-average CAGR of ≈3 percent. These growth figures present welcome compensation

Global potential for flexible capacity (baseline scenario)



Source: Arthur D. Little Analysis, IEA, Bloomberg

Aggregated earnings of 20 EU utilities by business segment



Source: Arthur D. Little Analysis, IEA

for some industry players, such as the European utilities whose earnings from traditional activities are either stagnating (in the case of retail & supply services) or significantly dropping (in the case of merchant generation), as can be seen from above figure. Utility earnings now stem from segments offering more stable cash flows, such as networks and generation based on contracted/regulated pricing models such as ancillary services or PPAs.

On top of that, flexibility usage can represent an additional and cheaper way to prevent utility imbalance, and therefore avoid paying penalties.

Benefit 2: Strengthen the relationship with prosumers

Unlike aggregators, utilities have access to portfolios of existing customers (B2B/B2C), with insight into their current energy consumption (patterns). Flexibility service offerings would provide utilities with the opportunity to strengthen their relationships and increase customer retention.

On the one hand, utilities can use flexibility services to help customers save money by lowering their energy bills, as well as to monetize their newly acquired assets such as residential batteries (plus provide related subscription-based services such as maintenance contracts). This can be achieved by changing customer consumption behavior (e.g., shifting consumption away from peak periods), or even optimizing asset use of prosumers (e.g., releasing energy from residential batteries when it is the most valuable). On the other hand, the utility can leverage the flexible capacity provided by consumers to optimize its own operations across the value chain. The utility can then improve its asset management by, e.g., choosing to (de-)activate a virtual power plant (VPP, flexibility from the customers) instead of using a traditional generation asset.

Benefit 3: Protect the market position in the home country while achieving growth internationally

Multiple utilities have secured solid positions as large DSR aggregators, both domestically and internationally (e.g., Centrica, Enel, Engie.). (See "Virtual power plants – At the heart of the energy transition"[1].) This combination of "retain" (domestic market) and "gain" (new geographies) creates two sources of return for such initiatives.

Domestically, the flexibility market allows utilities to access flexibility income streams (as stated in "Benefit 1"), as well as fend off the rising number of aggregators in many markets. Non-incumbent aggregators do not only exploit revenue streams that utilities could tap into, but they also develop strong relationships with consumers and other players in the ecosystem. In this regard, aggregators threaten the market position of traditional utilities by offering one-stop-shop approaches that allow customers to subscribe to flexibility services combined with energy management services (which increases their energy efficiency and prosumer asset usage), as well as "traditional" energy contracts.

Entering a new market for flexibility services internationally does not typically require the same expensive fixed-asset investments as those needed to enter energy generation and supply markets. Moreover, a foreign flexibility services market allows the new entrant to interact and develop relationships with not only consumers, but also transmission and distribution system operators and other utilities that own physical generation assets. As such, offering flexibility services is one of the best and asset-light routes for a new player to enter an existing electricity ecosystem.

Enel is a good example of a utility that decided to take a significant stand in the flexibility services market both domestically and internationally, through its subsidiary, "Enel X". above figure provides an overview of the main tenders for flexible capacity that Enel X was awarded in 2018, some of which enable Enel to develop dominant market positions in the local DSR market. Its 17 percent market share in Japan and 40 percent market share in the Irish DSR market allow Enel

Illustrations of Enel's 2018 deals

165 MW	■ Enel X was awarded the delivery of **165 MW** of demand-response resources in **Japan** following the completion of a tender for balancing reserves launched by a group of Japanese utilities ■ Enel has became the **largest independent demand-response aggregator in Japan**, and will nearly triple its VPP in the Japanese market with a **market share of 17%** when the new programs begin in July 2018
157 MW	■ Enel X was awarded market commitments to deliver **157 MW** of demand-response resources in the **for-warc capacity market** by the Independent System Operator for **New England** (ISO-NE) ■ With this award, Enel also enters the demand-response market in the states of Connecticut and Vermont, broadening its footprint in the US
62 MW	■ Enel X was awarded a total of **62 MW of flexibility resources** drawn from its own industrial and commercial customers in the **last two pilot auctions launched by Terna** (TSO) ■ This also includes a **forward supply of resources** reserved for holders of virtual consumption units to participate in the dispatching services market (UVAC)
217 MW	■ Enel X was awarded the delivery of **217 MW** of demand-response resources following the completion of **Ireland's first capacity-market auction,** launched by EirGrid (TSO) ■ Enel will hold **40% of the demand-response market in Ireland, with a** total of Enel's VPP in the Irish market expected to grow by 60% year-over-year to the awarded 217 MW (from the current 136 MW)

Source: Arthur D. Little Analysis

1 www.adl.com/VPP

to be one of the largest providers of flexibility in both these geographies. The total amount of flexible capacity awarded to Enel X equals approximately 600 MW. Enel X is currently following an aggressive inorganic growth strategy, and has already acquired multiple energy management companies, such as EnerNOC and Demand Energy.

Another notable example of such a strategy is the acquisition of the aggregator REstore by the UK-based utility Centrica, which allowed the utility to become present in foreign markets and pursue its ambition to further develop its position within the US market. More recently is the announcement of Engie, which has acquired a majority stake in Kiwi Power.

However, it is important to keep in mind that not all markets are equally attractive for DSR participation and/or development (by foreign players). Our support to utilities and investors in the assessment of geography attractiveness highlighted the disparity of regulation and market design within and outside Europe. Below figure provides a high-level assessment of some EU DSR markets. We distinguish multiple factors to consider when evaluating DSR market attractiveness. The most important are the level of competition, level of regulation and degree of industrialization. From a regulatory point of view, Ireland, the UK, France, Belgium, Switzerland, Finland and Italy are the most developed markets, with efficient policy frameworks already defined. In some other markets, such as Portugal and Spain, the limited push from the regulatory authorities and the TSO currently restrain the market potential. Most Eastern European countries still need to define their regulatory frameworks on flexibility, as the lack of this is increasing the uncertainty and the associated risk of a potential market entry. However, with the emergence of electric vehicles in some Eastern countries, we anticipate regulations to be clarified. However, the markets with favorable regulation are also typically the most competitive ones, which makes market entry more complex and puts pressure on potential returns. In terms of size, the highly industrialized markets in Eastern Europe show very high potential, although this is detracted from by a significant level of risk resulting from the uncertain and/or inexistent regulatory frameworks for flexibility services. As a result, utilities considering international expansion through flexibility services will need to clearly define their entry strategies, considering local specifics, and ensure their international portfolios are well balanced.

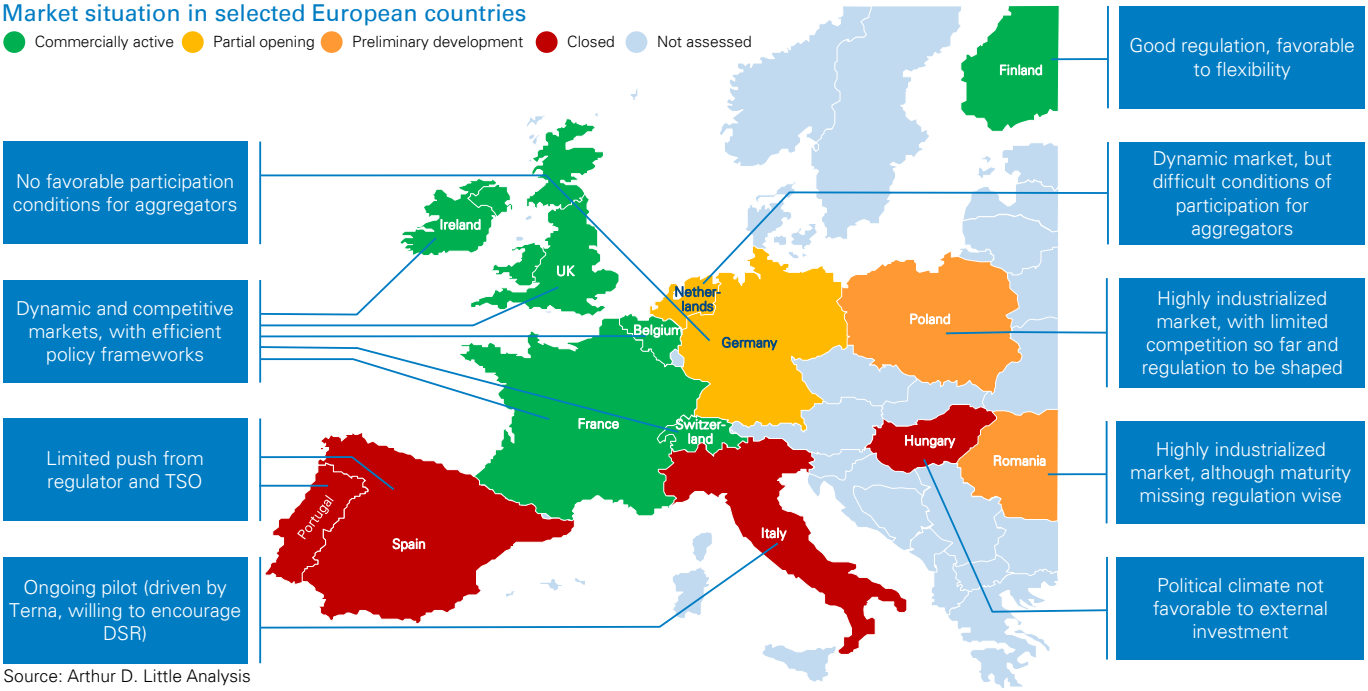
Recommendations to utilities: Key success factors to catch the opportunity

Create attractive value propositions

To be successful in a crowded flexibility market, utilities will need to differentiate themselves from other, often more agile and innovative, market players. However, we have advised our clients to create attractive value propositions towards their customers based on:

1. Strong presence and in-depth knowledge of the energy value chain and ecosystem to provide a full range of services. This includes load and supply aggregation, as well as energy management services (e.g., helping industrials identify more flexible manufacturing processes).
2. Ability to provide a one-stop-shop approach for all the consumer's electricity/energy-related needs. EDF Luminus is a good example. It has evolved from a gas and power supplier to an integrated energy partner. The company offers a combination of energy (electricity, with or without gas), flexibility, assets (PV panels, batteries, EV chargers, etc.), maintenance of the assets, and energy management. Although this can be achieved either fully in-house or using specific partnerships, taking a leading and coordinating

Market situation in selected European countries



Source: Arthur D. Little Analysis

role enables utilities to remain in charge of the customer relationship and experience. This includes more advanced service offerings, e.g. smart-home services, in which the utility becomes a central orchestrator of the smart-home ecosystem, enabling a variety of services with a single contract.

3. Flexibility service offerings must be attractive to customers, which implies that the remuneration for the provided flexibility should outweigh the (opportunity) cost of providing this flexibility. Although this seems to be trivial at first sight, the business case is often not obvious given the current market design and offerings. Utilities that already serve suites of offerings to these customers can apply creative pricing to capture the customer at entry point (including cross-subsidizing of multiple offerings to the client).

Educate the market and aggressively prospect for clients

Although the tangible benefits of flexibility towards virtually all players in the ecosystem have already been proven, many market players still need to be better informed and educated. This includes industrials and consumers who may be distrustful of the technology, but it can also mean grid operators active in countries where flexibility has not yet taken off. Given their position in the ecosystem, utilities should take a proactive role in educating the various players in the market. This includes aggressive prospecting to "recruit" sources of flexibility.

Develop the required skills and know-how

Utilities need to develop the right skill sets to act as full providers of demand-side response and energy management services. This should be a combination of the existing skill set in commercial, trading, legal, and financial capability and the required technical skills for flexibility management. These can be built organically or inorganically, by acquiring an aggregator.

Contribute to shaping regulatory frameworks

In order to ensure that the flexibility market will provide a stable source of revenues, utilities need to engage with regulators and other market players to shape a stable and transparent regulatory framework in which business models can be built. The regulatory framework must facilitate participation through attractive and fair market mechanisms that prevent discrimination between actors in the energy value chain, as well as between end users.

Arthur D. Little's experience

Arthur D. Little supported many transactions in the flexibility area, supporting utilities and investors in strategic reflections on acquisitions and establishing themselves in foreign geographies, as well as on setting out on the path to make their flexibility strategies fruitful. With our clients, we have qualitatively and quantitatively explored opportunities for investing in flexible assets (e.g., large-scale and behind-the-meter batteries) in Europe, the US, Asia and other parts of the world, and identified the capabilities required to succeed.

Authors

Kurt Baes, Florence Carlot and Maxime Dehaene

www.adl.com/Flexibility

The evolution of the street lighting market

What is its role in smart city development?

Executive summary

The street lighting market is growing globally, boosted by regulatory policies that encourage energy efficiency, IoT convergence, LED price drops, and a new business model "as a service" in different industries. The new concept of "smart poles" is also growing around the world, with use cases that range from basic LED replacement and remote control to the more innovative concept of "smart poles" equipped to offer video surveillance services, air quality monitoring, fiber or Wi-fi connectivity (e.g., Enel's JuiceLamp).

Public lighting infrastructure has three key features that position itself as potential strategic assets for smart cities' concept, enabling the development of a common platform with significant cost synergies: capillarity, electrification and connectivity. This study aims to analyze the main smart city services that can be developed leveraging public lighting infrastructure, identifying the main bottlenecks and roadblocks that prevent large-scale deployment and developing key recommendations for companies entering this new market. In order to do this, we analyzed a number of relevant use cases and interviewed different players along the value chain (Enel X, TIM, Open Fiber, Axxon, Arianna LED and two Italian municipalities). The main findings are summarized below:

- Lighting poles represent a strategic infrastructure for smart city development (and, in particular, for video-surveillance services and autonomous driving) thanks to their capillarity, connectivity and electrification.
- A significant number of pilot projects are emerging in many countries, but with a lack of large-scale deployment.
- The main constraints for large-scale development are related to a demand not yet in place (players need to create demand for smart services, and this takes time), main buyers (public administration) that have financial constraints and lack technical expertise, and the presence of several stakeholders that need to find the right way to collaborate.
- Public lighting operators need to innovate and push on technology innovation and new business models/ partnerships to effectively leverage their infrastructure and participate in this new competition area.

1. Market overview and key drivers

Demand

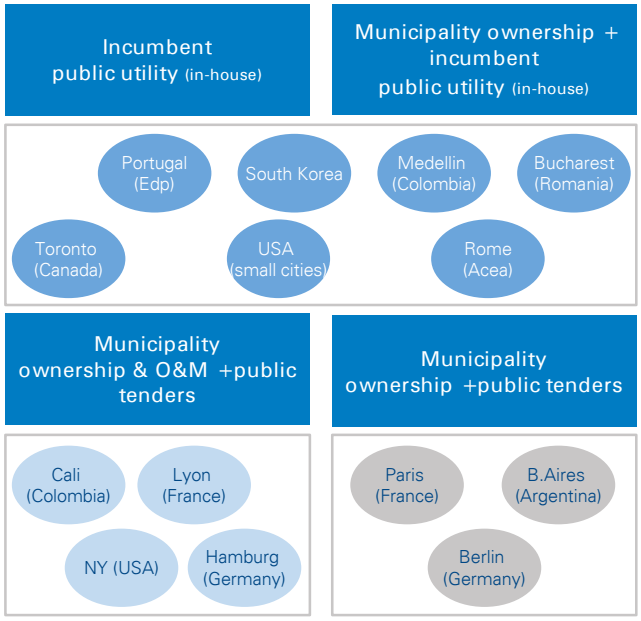
Worldwide, there are around 320 million street lighting poles, with Asia accounting for 25 percent, Europe and North America for 20 percent and South America for 10 percent. Countries and municipalities differ in terms not only of sizing, but also LED penetration, capillarity and business models. The market is driven by several factors, among which are regulatory policies, IoT convergence, and LED price, in addition to the culture and morphology of each area.

Worldwide lighting density, in terms of urban population for each lighting point, is on average around 13, ranging from 7 European countries to over 20 in Asia-Pacific.

As of today, average LED penetration at a global level is still below 15 percent, with significant differences among countries. For example, Japan and Canada showed higher LED penetration rates (around 44-50 percent), while South America showed an average rate below 5 percent.

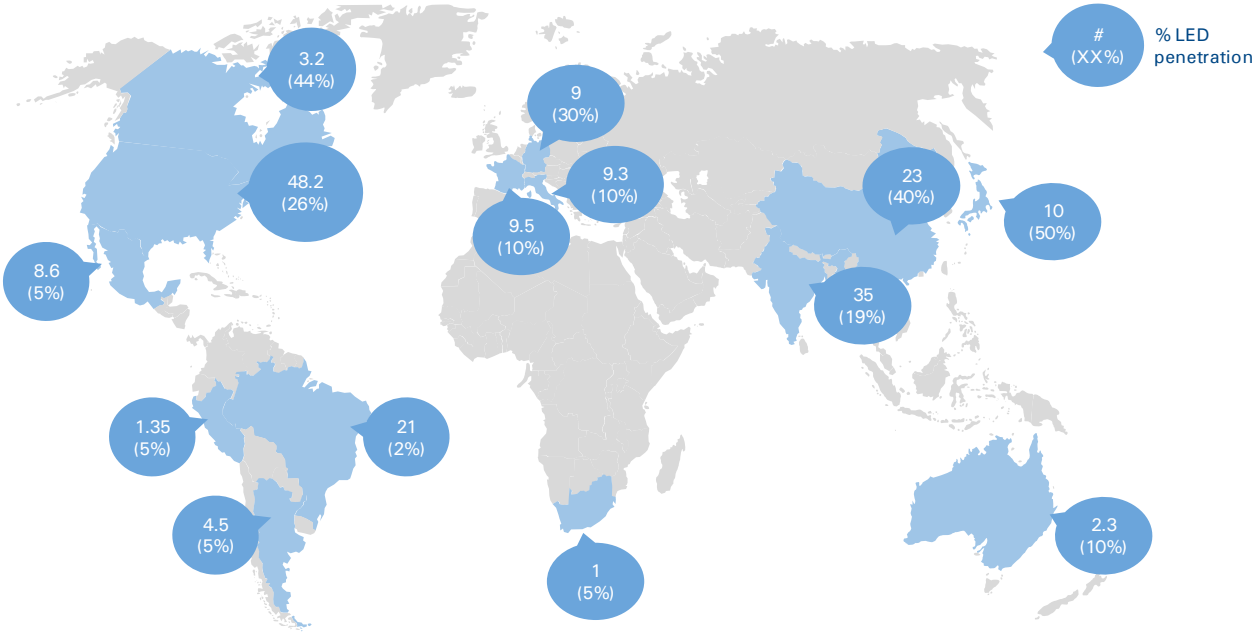
In Europe penetration is around 10 percent, with only Germany above, and in USA around 26 percent. Even within the same

Figure 2: Lighting management models



Source: Arthur D. Little analysis

Figure 1: Lighting points by geographical area



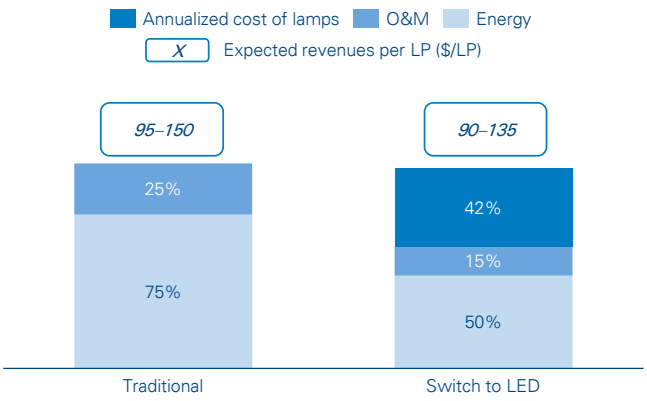
Source: Arthur D. Little analysis

countries, LED penetration are quite different: some big cities have already reached 100 percent (e.g., Milan and New York), while small ones are still struggling, mainly with financial barriers.

The business case for switching to LED is already strong, as LED technology can generate savings of 50–80 percent of energy costs (which accounts for around 75 percent of total cost, while the other 25 percent is related to O&M).

This allows payback of the initial investment and generation of enough profits to cover the annual cost of lamp replacement.

Figure 3: The business case for switching to LED



Source: Navigant, Market and Markets, Arthur D. Little analysis

Key drivers

Our study shows three key drivers which are boosting the development of smart street lighting:

1. **Regulatory policies**: Policies encouraging the use of energy-efficient lighting systems are also helping to propel market growth.
2. **IoT convergence**: Smart city development and advanced remote control systems drive the growth of the VAS segment.
3. **LED prices drop**: Falling costs and improvement in quality are making LED the default option for lighting.

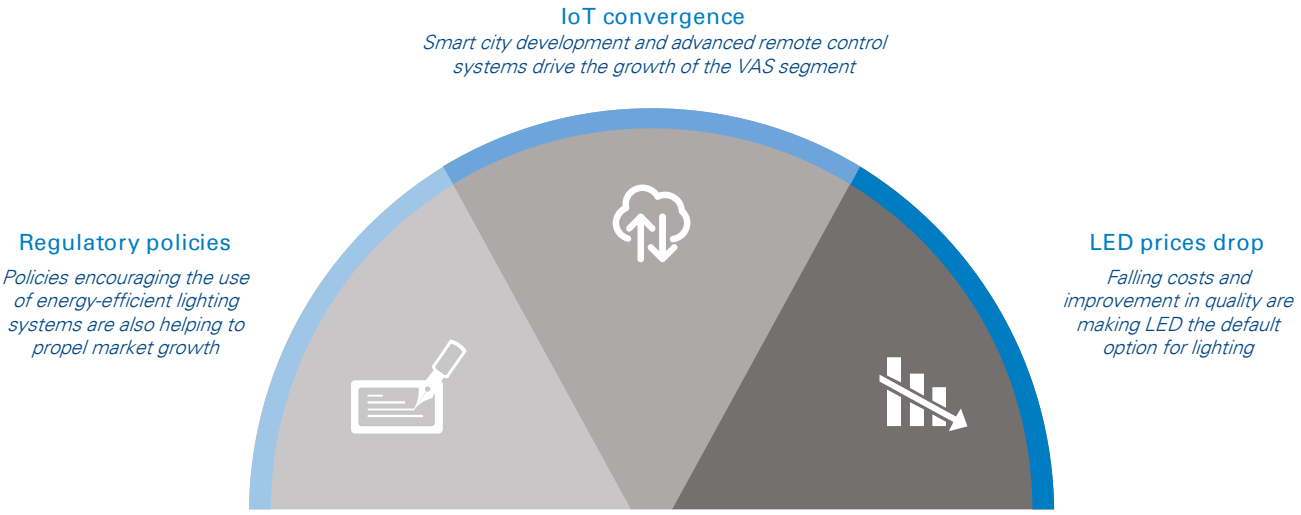
arianna
light looking forward

We asked Arianna LED – an Italian company specializing in the design and manufacture of LED lighting systems – what were the main constraints that players faced in "LED transitions" and why the transition process is slow:

- Complex regulation, with several entities engaged.
- Project sizing: a profitable business case requires a minimum of 20,000 street lighting points – potentially attractive to an energy service company (ESCo) aimed at mitigating municipalities' upfront financial constraints.
- Political conflicts that prevent municipalities from collaborating to organize tenders and benefit from scale.
- Product requirements.

A recommended solution for small municipalities is to pool their decision-making and purchasing power in order to leverage economies of scale and access competitive LED replacement business cases (e.g., as 35 municipalities in southeastern Pennsylvania have done).

Figure 4: Key market drivers



Source: Arthur D. Little analysis

Regulatory policies

Smart street lighting projects represent a fast and relatively simple way to pursue emission and energy efficiency targets.

At the United Nations Climate Change Conference (COP 21) in Paris in December 2015, 195 countries adopted the first-ever universal, legally binding global climate deal. The agreement set out a global action plan to put the world on track to avoid dangerous climate change by limiting global warming to well below 2°C. To achieve this, the world must stop the growth in greenhouse gas emissions by 2020 and reduce them by 60 percent of 2010 levels by 2050. Furthermore, in 2016 the European Union published the Clean Energy for All Europeans rules, or so-called "Winter Package", for reforming the European Union electricity market.

Since 2000 Europe has issued many directives about pollution, and after the Paris Agreement it developed different long-term plans, which included increasing targets in 2020, 2030 and 2050. 20 percent of the whole EU budget for 2014-2020 is spent on climate- related actions and the Commission has proposed raising this share to at least 25% for 2021-2027. In addition, on October 3, 2018 the European Parliament voted for a 20 percent cut in CO_2 emissions from new cars and vans in 2025, as well as a 40 percent reduction in 2030, in a bid to speed up Europe's electric car revolution. At the end of 2018, the European Commission defined a vision for a modern, competitive, prosperous and climate-neutral economy, aiming at achieving net-zero greenhouse gas emissions by 2050 through a socially fair, cost-efficient transition (Comm. 773/2018).

In 2017 the US administration decided unilaterally to stay out of the Paris Agreement. The US is one of the very few large, energy-consuming economies that do not have national energy reduction targets in place, although it has adopted stringent energy codes for new buildings.

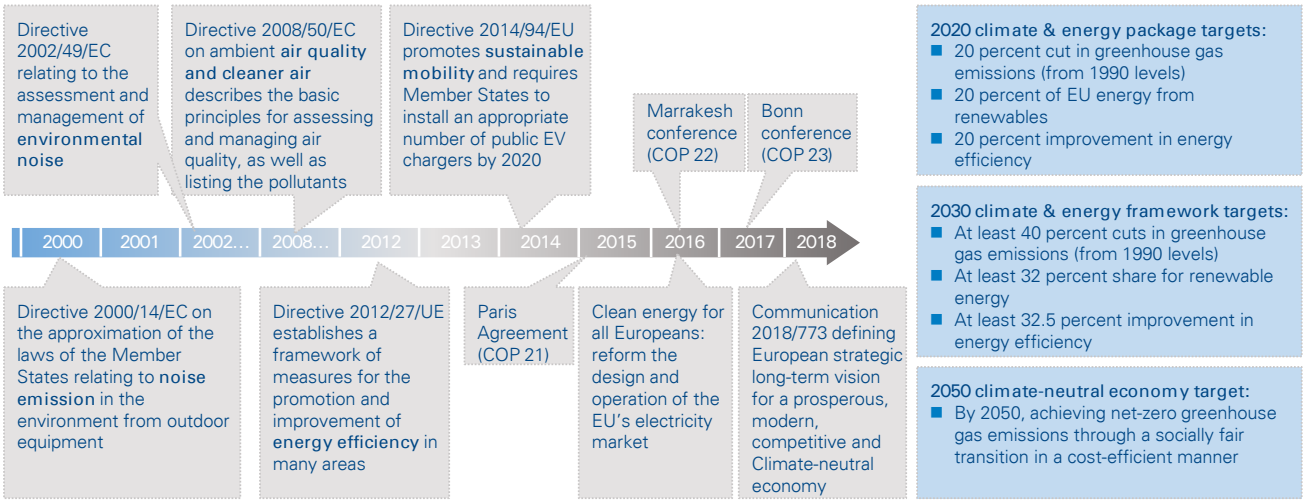
Canada showed strong commitment to GHG emission reduction with a target of 17 percent below 2005 levels by 2020 and 30 percent by 2030, equivalent to 607 megatons as defined by Canada's original 2005 baseline. In addition, several energy efficiency initiatives have been defined at either province or federal level on a sector-by-sector basis.

Other local or national initiatives have been promoted by several countries in the far east and Asia, setting ambitious targets in terms of energy efficiency.

South Korea's second National Energy Master Plan established a goal of 13 percent below the business-as-usual emission level by 2035. It also implemented various regulations, including a plan for an emissions-trading system (financial support and tax credits).

China launched many initiatives in the run-up to COP 21, and developed its climate diplomacy, showing strong improvement in terms of energy intensity. This included a new emission trading system aimed at reducing carbon, which should be up and running in 2019.

Figure 5: EU regulatory policies and future strategies



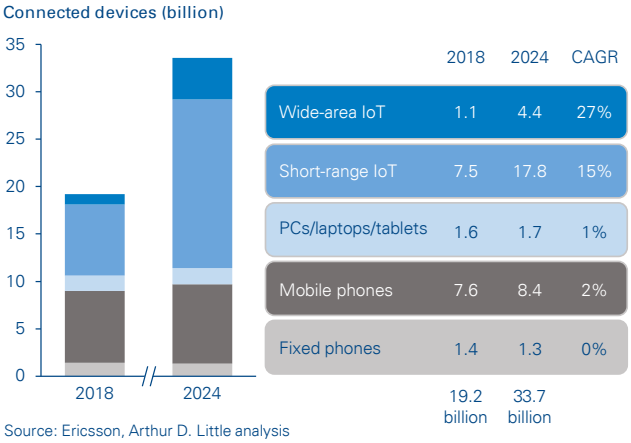
Source: European Commission, Arthur D. Little analysis

IoT convergence

The Internet of Things is the connection of everyday products such as cars, alarm clocks, and lights to computing devices via the internet to allow them to exchange data. Street lighting will benefit from this, as lighting poles will become hosting infrastructure for several connected devices (e.g., sensors, video cameras, EV chargers).

As reported in Figure 6, in 2024 there will be ***22 billion connected IoT devices***, with an average IoT devices CAGR (wide-area and short-range) of 17 percent.

Figure 6: Connected devices forecast

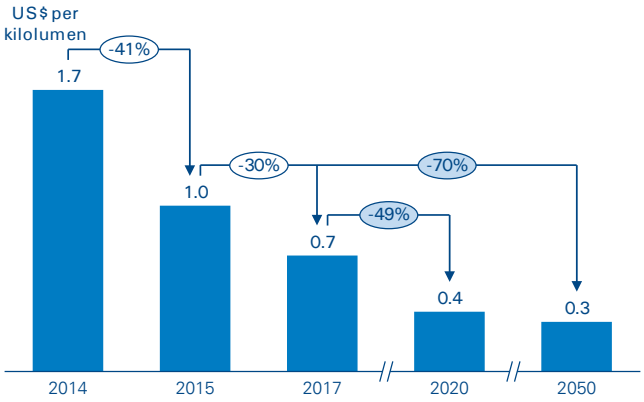


Source: Ericsson, Arthur D. Little analysis

LED prices drop

LED prices are expected to strongly decrease in the medium to long term (up to 70 percent by 2050 for USA as reported in Figure 7) and high-quality products (e.g., RGB W) which are able to provide different light temperatures and new services (e.g., adaptive lighting) have been placed on the market.

Figure 7: US LED price projections

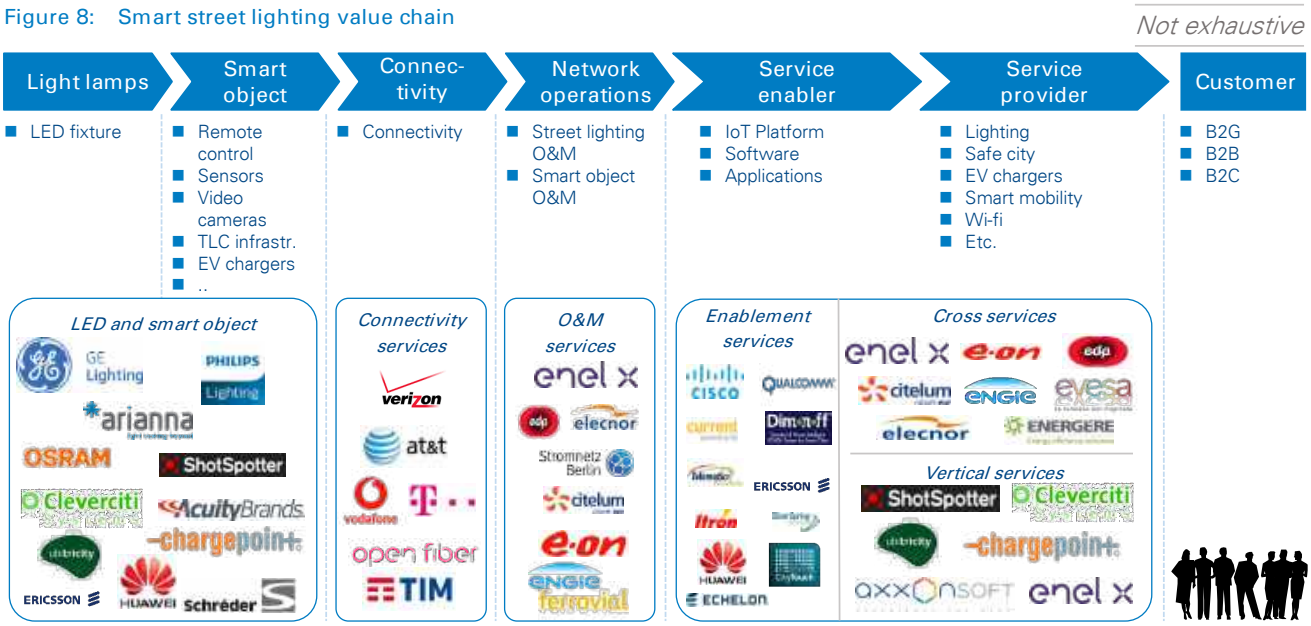


Source: DOE, EIA, Arthur D. Little analysis

Value chain and main players

Technology is deeply changing the lighting market, making it into a new booster/enabler for smart city development. However, as a consequence, complexity of the sector's value chain is increasing and new players are entering the market, as reported in Figure 8.

Figure 8: Smart street lighting value chain



Source: Arthur D. Little analysis

Utilities typically manage public lighting services, acquiring light lamps from manufacturers, developing O&M services, and defining service-level agreements and related remuneration with municipalities. Now the value chain is changing, with new players entering the market and new partnerships arising. (These include, for example, telco operators that provide connectivity; LED manufactures that, in addition to lamps, are developing their own IOT platforms; vertical players that provide solutions such as EV charging stations and video surveillance services).

In that context, the lighting pole can play the role of "aggregator" in terms of both ***infrastructure***, which hosts all key connected devices, and **partnership enablement**.

However, players struggle to find the right way to collaborate and develop effective business models together.

enel x

Enel X is a global company belonging to the Enel Group with a long-standing experience in installation, operation and maintenance of traditional public lighting. The company is currently focusing its efforts on transitioning the existing asset base to more efficient technology, as well as providing technologically and digitally advanced solutions to B2G customers (municipalities and the like) to support a 'smart' urban environment in key application areas in public lighting, mobility, fiber optic-based connectivity, and urban resilience.

As a perfect example of technology integration, efficiency and innovation, Enel X has developed Juice Lamp, an innovative product that combines the latest available lighting technology with two chargers for electric vehicles. The design is attractive and can be adapted to any urban context thanks to its 4 differentiated pole styles.

Features:

- LED light pole combined with remote controlling technology and option to install adaptive lighting features.
- Two integrated chargers with capacity of up to 22kW each, by no means equal to the public standing technology offered by Enel X.

Benefits:

- It can be fitted to any street environment thanks to its range of heights, colors and design: there are 3 'modern' styles plus a 'classic' one that fits well within historic sections of cities, or for towns with a specific sensitivity in this area.
- Quick charging, thanks to the Juice Box connectors which each have a capacity of 22kW.
- Interoperability with other potential mobility service providers and possibility to couple any street lighting devices.
- Possibility to integrate video surveillance, traffic analytics, environmental monitoring, connectivity, other smart services.

Scope

With no specific constraint or limitation to its implementation, Enel X has also developed an innovative tool 'YoUrban©', a single platform with a twofold application: a mobile app for city-based individuals and a web-based management tool for municipalities.

YoUrban© allows individuals to promptly and easily alert municipalities about lighting points malfunctioning (whose identification is easy thanks to a GPS system) while following any ensuing development, sharing the positive outcome of the maintenance activities on social media, getting access to a section including 'news' and earn rewarding points that can be utilized following instructions included in the app.

At the same time, municipalities get an advantage in terms of faster and more cost-effective management of maintenance activities given that the portal allows a fully digitalized experience of activities like, amongst others: i) getting dashboards showing the most relevant key performance indicators about the level of quality of the public lighting system; ii) monitoring of closed/open incidents for urgent interventions, iii) visualization 'on map' of the assets under management and customizable statistics about the number of reported incidents, average closing time, etc., iv) direct connection with any related call center and engineers; v) direct connection with suppliers and option to accept online offers and cost estimations for the maintenance and repair activities offered by Enel X.

2. The smart revolution

Public lighting infrastructure has three key features that position it as a potential strategic asset for smart city development: capillarity, electrification and connectivity.

Finding new revenue streams implies clear understanding of enablers, constraints and a successful business model.

Arthur D. Little's "Smart city framework" includes the key pillars to help municipalities leverage their street lighting infrastructure to successfully set up and implement strategies that will transform them into smart cities.

Several cities have already implemented connected LED streetlights using different technologies depending on the smart city's applications. (Examples include the IEEE 802.15.4g wireless RF mesh architecture used in Miami and Paris, as well as the combination of Vodafone machine-to-machine SIM cards with Vodafone's M2M wireless network, which was adopted in Los Angeles and Jakarta.)

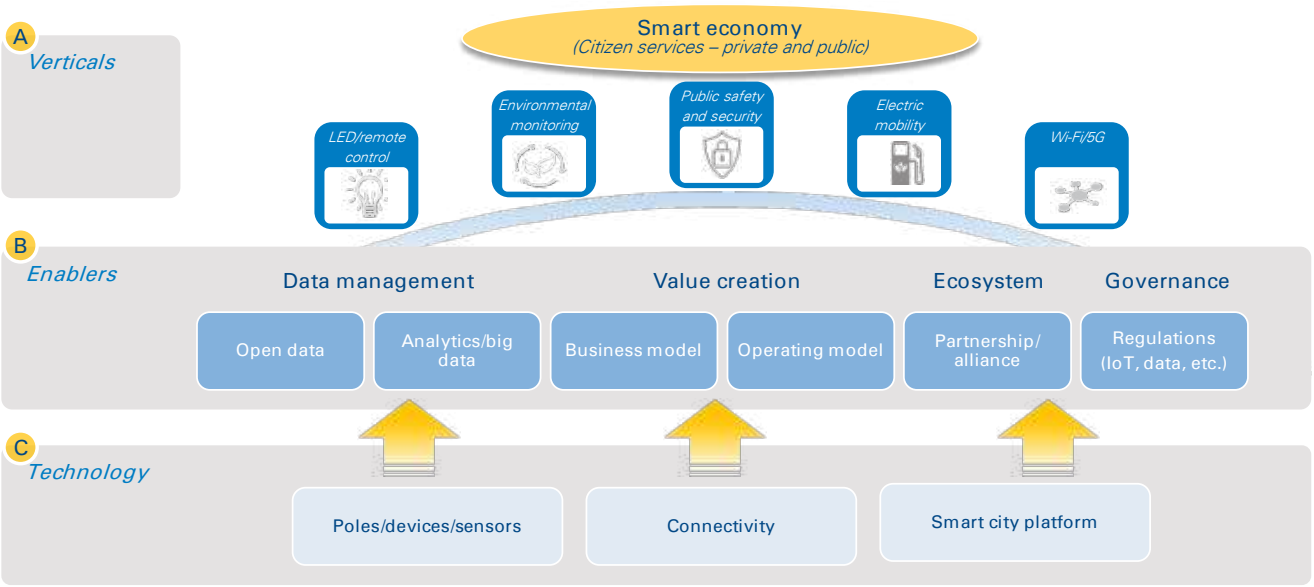
One of the main infrastructure challenges is to balance the network capacity requirement against the different smart city applications (cost of network roll-out versus benefits and revenues from applications developed).

In many cities around the globe FTTH/C plans are ongoing, often using lighting infrastructure to minimize the cost of the roll-out. This could also represent a strong boost to the development of smart applications.

An open and shared platform is one of the key elements to maximize smart city opportunities, as sharing capex and opex increases the profitability of each use case and enables a larger deployment. However, the current context tells a different story, particularly in the big cities: the majority of smart city initiatives are still represented by pilots in specific verticals.

In the following sections of the report we will focus on some of the possible "verticals", outlining some quotes from different players.

Figure 9: Arthur D. Little's Smart city framework



Source: Arthur D. Little analysis

Figure 10: Top 10 cities implementing connected streetlights

Rank	City	Connected streetlights	Country
1	Miami	500,000	United States
2	Paris	280,000	France
3	Madrid	225,000	Spain
4	Los Angeles	165,000	United States
5	Jakarta	140,000	Indonesia
6	Montreal	132,500	Canada
7	Birmingham	130,000	United Kingdom
8	Dongguan	120,000	China
9	Buenos Aires	108,500	Argentina
10	Milan	101,060	Italy

Source: IOT Analytics, Arthur D. Little analysis

open fiber

Open Fiber, an Italian infrastructure operator, aims to bring ultra-wideband optical fiber to all the major cities in Italy and connect industrial areas, in order to build an ultra-wideband network that is as widespread and efficient as possible.

According to Open Fiber management, fiber roll-out plans are in progress in several countries, and the public lighting infrastructure is the preferred hosting infrastructure for fiber development thanks to capillarity and cost efficiency (lower €/meter compared to other network infrastructures or to digging).

In Italy, the "destinazioni d'uso" represent a potential roadblock for smart city services because utilities are often not allowed to use the poles for developing additional services (e.g., smart services), apart from street lighting, without an agreement with the municipality.

Open Fiber aims to enter the smart city value chain by developing connectivity infrastructure and providing connectivity O&M services.

Air quality and noise monitoring

The environmental topic is key both for government and municipalities, and it is increasingly attracting the attention of citizens:

- According to the WHO (World Health Organization), more than 80 percent of people living in urban areas are exposed to air-quality levels that exceed safe limits, and 4.2 million deaths every year are related to exposure to ambient (outdoor) air pollution.
- National and regional public entities and municipalities are responsible for keeping the natural environment under control, verifying compliance with environmental regulations and defining measures to close the gaps.
- Citizens can directly monitor the levels of pollution in their cities thanks to the increasing number of apps available in the market, such as AirVisual, BreezoMeter, Plume Air report, WideNoise and Airveda.

Environmental monitoring has historically been based on static and sparse measurement stations, but recently, many cities around the world have been adopting mobile laboratories to collect more granular data.

For instance, in Italy, ARPA Lombardia counts on only 150 stations in the Milan province and 106 mobile laboratories in the Lombardy region.

Across the Ile-de-France region there are 60 stations and mobile laboratories in specific areas or subjects of interest (such as airports, train stations and the Paris ring road), and 71 stations are set up in Washington DC.

Noise-monitoring sensors, apart from generating continuous, dense data on urban noise, provide significant data to support city-wide planning decisions such as traffic planning and school placement, as well as to inform and monitor public health initiatives related to environmental conditions.

Lamp poles, thanks to their widespread distribution, can easily host air and noise sensors: in fact, these sensors are constantly becoming smaller, without compromising reliability, and lighting poles may offer a cost-effective, quality service (e.g., more granular data) at a lower cost than other available solutions (See Figure 11).

Figure 11: Environmental monitoring

	Static stations	Mobile laboratories	Sensors on buses	Sensors on light poles
Owner/ concessionaire of infrastructure	Environmental agency supported by the municipality	Environmental agency supported by the municipality	Public transport operator *(typically local operator, one for each city)*	Public lighting operator *(the municipality directly or an electric utility, which can be a local or national operator)*
Capillarity of infrastructure	Low	Medium	High	High
Data accuracy	Limited monitoring coverage restricts the accuracy of the monitoring, despite the sensitivity of analysis obtained in the laboratory	Medium monitoring coverage, higher detection limits and lower sensitivity than analysis obtained in laboratory conditions; strong influence of environmental factors restricts accuracy of monitoring	Mobile sensors can be used to sense environment data over a larger area	As light poles are located throughout a city, they are the ideal hosts for a wide array of sensors, and they can collect a wide range of data
Costs	Implementation and maintenance costs are higher because the works should be carried out by technicians sent to different fixed-sensor sites	The use of portable field instruments offers a possibility of cost-effective, non-destructive, real-time, direct, on-site measurements compared to static stations, but logistics and personnel costs are higher compared to other solutions	Less expensive to implement and maintain (works can be carried out in bus stations)	As the sensor can draw power from the light pole and use the communications equipment embedded in the smart street light, implementation can cost much less than finding and allocating dedicated sites to air quality measuring equipment
Synergies	NA	NA	NA	With other smart services

Source: Arthur D. Little analysis

TIM Bus as Sensor – Air Quality Control

The service developed for the municipality of Catania (currently been testing on other municipalities) implies the usage of city transports during their regular daily route in order to track the air quality in real time enabling on-the-edge IoT services for Smart City. The Mobile Sensing Station installed on the bus measures the level of pollutants along the route sending them to the Smart IoT platform through the TIM mobile radio network.

Data gathered and processed in cloud allow to create new services focused on several targets:

- Municipality: a web controlling dashboard to monitor the urban area air quality inside the Smart City Control Room
- Citizens: a mobile app that allows to receive green feedbacks/suggestions regard behaviors to be taken or not based on the level of pollution detected
- Third parties (e.g. Startup): Application Programming Interface provided by TIM (B2B), aiming at launching new apps developing new business models

Figure 12: Examples of sensor use

Sensors on light pole

- The city of Los Angeles was involved in a pilot: adding sensors to the light poles and adopting an open approach for environmental monitoring

LOS ANGELES | PHILIPS

Sensors on buses

- Waspmote has been used to control public transportation and monitor environmental parameters in several cities in Serbia

libelium

Source: Arthur D. Little analysis

Public safety and security

One of the main goals of governments and emergency services is to deliver safe, secure and sustainable cities ("safe city"), which requires several things:

1. **Integrated system**
   An infrastructure with common sensors connected by a shared network. Evolved from a disparate set of sensors with no interoperability.
2. **Multi-agency collaboration**
   Moving beyond shared infrastructure to sharing intelligence, operational procedures and planning.

3. **Situational awareness**
   Real-time information, with traffic data, sensor positions, resource locations, weather and other intelligence.

4. **Video data & analytics**
   Information collated from an array of city sensors and databases combined with video analytics, LPR, face recognition, behavioral analysis.

5. **Automated processes**
   All camera information is generated on one screen, alerts are registered, and the right operational procedure is generated.

Thanks to the Internet of Things (IoT) and connectivity services, safe city solutions enable governments and police departments to better protect their citizens from many threats; from terrorist attacks to natural disasters.

They also support other municipalities' services, such as public health, fire and rescue, border control and social services.

The basic hardware of the safe city is the video camera, used for public video surveillance and video analysis to prevent crimes. It relies on prevention/detection/response/recovery processes such as facial recognition, object missing, and following, which constitute the value offering.

The business case for video analysis is strong, as connected video cameras allow a better service in terms of probability of detecting a crime, reaction time, and therefore security, at a lower cost.

The total cost, including devices and software for video analysis, is much lower compared to that of a control room.

Surveillance footage is captured in full-color HD and recorded in the cloud, where artificial intelligence processes can view and analyze the video.

In the event of something suspicious, alerts are sent to the appropriate personnel, while sophisticated facial recognition technology helps alert teams when a known shoplifter has entered the store or area. The use of AI systems will improve surveillance quality and reduce personnel effort.

In addition to the security issue, one of the main reasons for the growth of video surveillance services – and probably the most important – is the increase of wireless broadband networks.

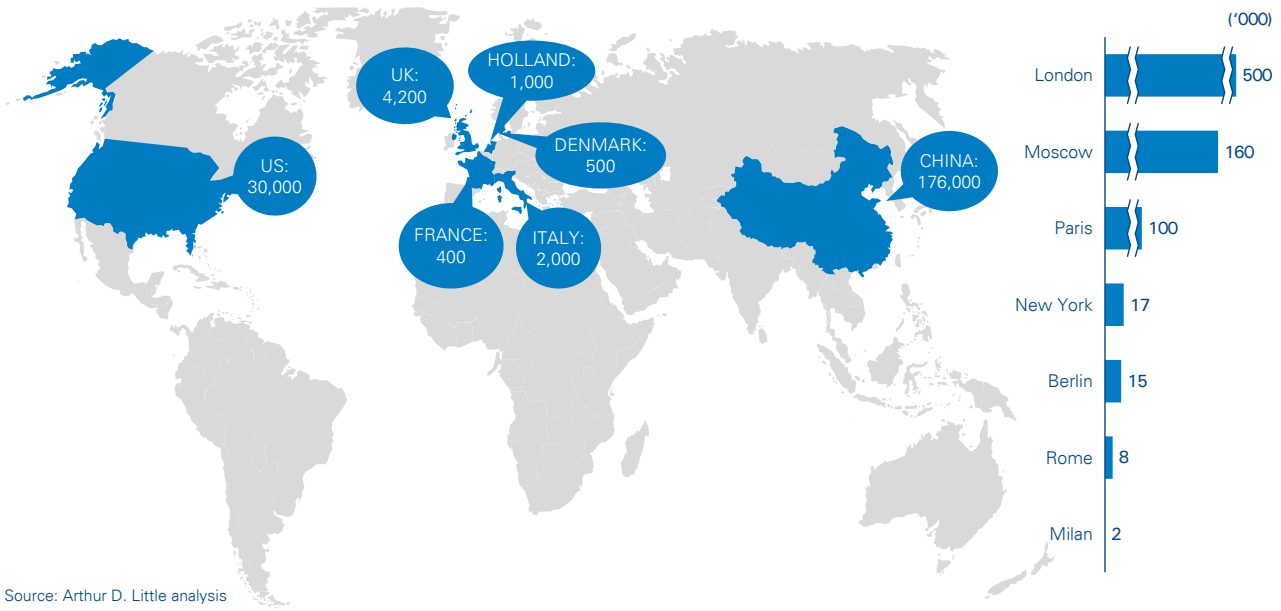
This is due to its reliability, high quality and cost saving compared to wired connection (no digging work and less manpower).

On the other hand, some relevant constraints need to be evaluated as fragmentation of service buyers, privacy issues and the public sector as the main buyer, with its limited budgets and inflexible labor market. In B2B, buyers could be big video surveillance companies.

Even with these constraints, we expect that connected cameras will grow across countries, although as of today the market is still limited in size.

Moscow is a good example of implementation of a safe city: a network of about 150,000 cameras has been set up to monitor city streets, residents, businesses and visitors. Currently, the cameras are used for several purposes such as to ensure trash is picked up, to crack down on speeding and red-light running, to monitor the compliance of street advertising, and to track snow removal.

Figure 13: Number of CCTV cameras by country and main cities



Source: Arthur D. Little analysis

AXXONSOFT

We asked Axxon – one of the world's leading developers of video management and physical security information management software systems – **if public poles could represent strategic infrastructure for development of smart services**. The answer was "absolutely yes", for the following reasons:

- The supply of electricity from the grid (even if it is not continuous, because there is energy saving in the objectives of efficient management). The pole can be controlled remotely or by local sensors; however, local control costs less.
- It can be connected to the fiber that guarantees broadband connectivity. Video surveillance takes advantage by backhauling compared to radio waves.
- It is an existing infrastructure – not very invasive, but widespread. It can be equipped with sensors that serve in other capacities. We consider that it takes a lot of cameras to guarantee the development of safe cities.

Below are use cases developed by some municipalities:

Figure 14: Safe city examples

Surveillance activities

- Free pilot on 4 LPs that combine LED lamps with real-time, 24x7 surveillance cameras, which collect images of vehicle and pedestrian activities

CITY of BOSTON | verizon

Gunfire detection

- By implementing street lamps with acoustic sensors and software, it is possible to detect gunshots and enhance inhabitants' personal safety

The City of SAN DIEGO | current + SST

Emergency response

- The university equipped campus LPs with emergency buttons that notify security and help to locate emergencies

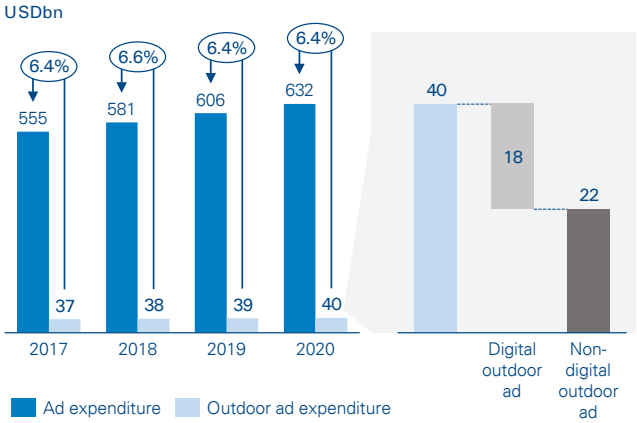
ILLINOIS

Source: Arthur D. Little analysis

Digital advertising and communication (digital billboards)

Outdoor advertising represents a limited part of global advertising expenditure, and could be divided into two macro-segments, digital and not digital, and where digital is expected to drive the growth of the market.

Figure 15: Ad expenditure forecast and outdoor composition



Source: Arthur D. Little analysis of Zenith data

The main advantage of digital advertising is real-time campaigns (compared to the average time of 20 days for traditional billboards) and programmatic buying, thanks to connected signage that can be changed based on location, audience and time (overcoming the targeting limitation of traditional outdoor advertising).

Public lighting infrastructure can be used to host digital signage with the advantage of capillarity and potential cost synergies (sharing cost with other smart lighting services), although some restrictions remain, such as road safety regulation. One of the most relevant applications is in the medium-sized municipalities, which are characterized by saturation of traditional outdoor advertising media (municipal billboards), even if prices are typically lower than in urban centers.

Some use cases can be found on the following page.

Figure 16: LED street-pole advertising and US public alert examples

Source: Arthur D. Little analysis

Electric mobility

Only a decade ago, vehicles with batteries and electric motors felt like a distant sci-fi dream. Today, they are shaping the lives of consumers and the strategies of car producers, utilities and governments.

Arthur D. Little identified the following main trends:

- Production on a massive scale of new, compact forms of energy, such as lithium-ion batteries, will drive the adoption of electric mobility solutions.
- Urban mobility demand is booming – in terms of passengers-kilometers per year, it is set to double by 2050.
- Regulations will ban sales of cars with petrol and diesel combustion engines in the long term, and gradually replace them with alternative engines.
- The market for cars with electric engines is experiencing high growth: by 2025, there are expected to be 26.2 million electric vehicles.

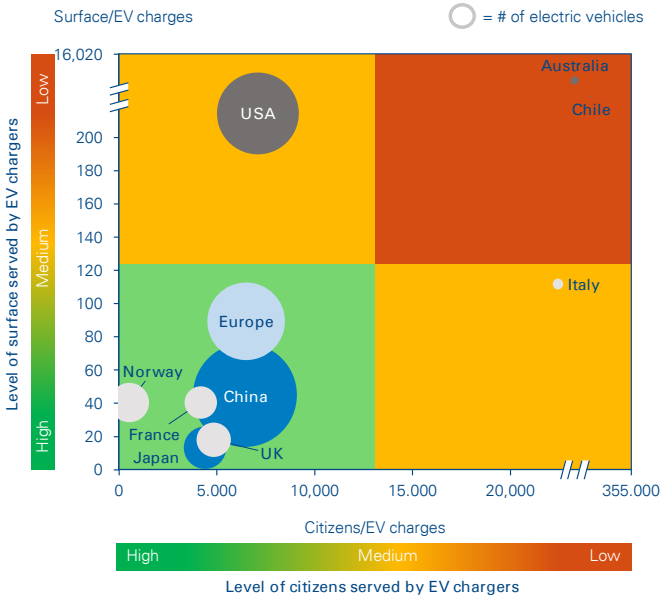
The global estimated number of EVs in 2016 was 2 million – a number led prominently by the US and China, with approximately half a million EVs each.

Currently, Japan has the best ratio of surface to EV charges (1 EV charge for 13 km²), and Norway has the best level of EV charges for citizens (1 EV charge for 535 citizens).

Chile, Australia and Italy have the worst levels of EV charges for citizens, but the total EV market for each country is lower than those of other countries.

The US, Australia and Chile have limited numbers of EV charges considering the extension of these countries.

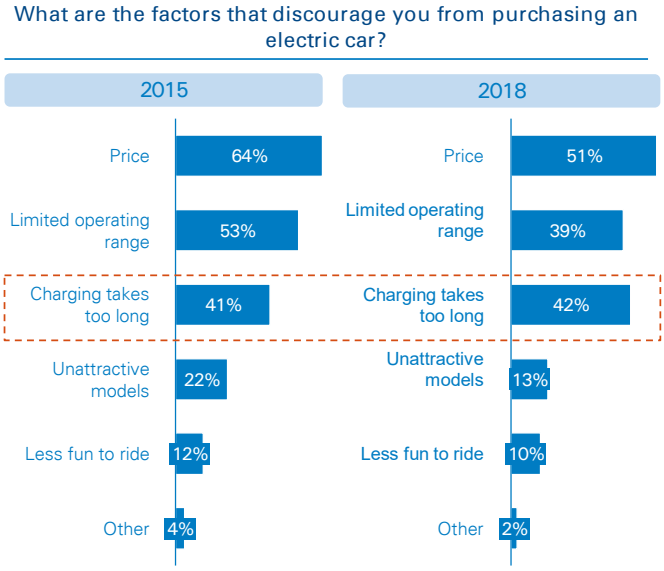
Figure 17: EV ratios



Source: Global EV Outlook – IEA, Arthur D. Little analysis

According to Arthur D. Little's "Future of automotive mobility" survey, the potential of electric mobility is still limited by the price of electric cars compared to that of traditional-engine cars, as well as the shortcomings related to battery charging (operating range and charging time). Strong development of EV infrastructure would help to solve both operating-range and charging-time issues.

Figure 18: Barriers to purchasing electric cars



Source: Global EV Outlook – IEA, Arthur D. Little analysis

As the availability of charging stations represents a barrier to large-scale development, regulatory policies are trying to boost EV charger infrastructure roll-out. However, public options are typically limited to destination charging points, while electric vehicles are expected to be mostly charged at home, overnight. This is feasible for households with off-street parking, but more difficult for those without.

Some use cases, reported below, confirm Lamp-pole with EV charging station embedded, as a potential solution to dealing with charging point scarcity, enabling public access and reducing installation time and overall costs.

Figure 19: New light pole examples

EV charging

20 LPs - 1400 $/LP

- Existing lampposts equipped with new EV charging sockets for a pilot number of residents who have no access to off-street parking collect real-time data on the city's environment and infrastructures

London Borough of Hounslow | ubitricity

4G Light and charge system

1.2 mn $

- Charging solution that can be flexibly integrated into existing infrastructure and adapts perfectly to every cityscape

City of Seattle | eluminocity

Smart poles

2 LPs

- JuiceLamp is an innovative solution that integrates public lighting with EV charger, video surveillance services, quality monitoring, fiber or Wi-Fi connectivity

Ciudad de Pescara | enel x

Source: Arthur D. Little analysis

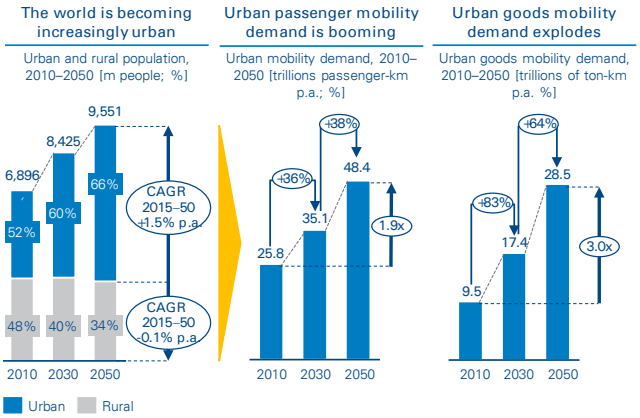
NISSAN

According to Nissan, a leading Japanese OEM, around 95 percent of EV charging will be at low speed, and smart poles could be a good solution to overcome cost barriers.

Smart mobility

Mobility demand is booming. The mobility landscape is being reshaped, and urban mobility poses a massive challenge to metropolitan authorities and businesses, as well as great opportunities. The global demand for passenger mobility in urbanized areas – in terms of passengers to kilometers per year – is set to double by 2050. A supplementary factor affecting the traffic issue is the massive growth in the number of individual journeys taken daily since 2010, which puts increased pressure on existing urban mobility systems. Even larger growth is expected in the field of goods mobility, especially in dense urban areas, due to the growing importance of e-commerce and the accompanying boom in demand for last-mile delivery.

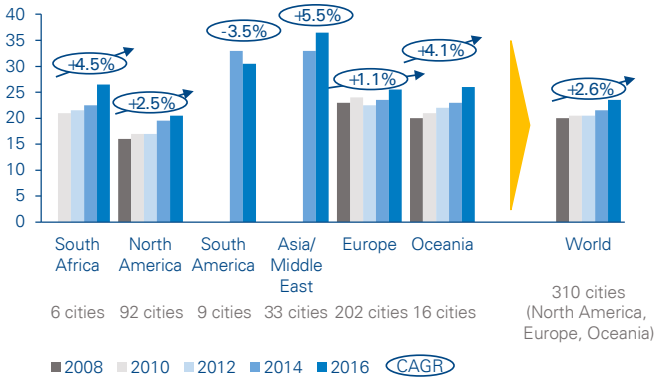
Figure 20: The future of mobility will be urban



Source: TomTom traffic index 2008-2016, Arthur D. Little analysis
TomTom measures the congestion level (%) as the increase in overall travel times when compared to a free-flow situation

As a consequence, congestion is increasing.

Figure 21: Evolution of congestion level per region [percentage, 2008–2016]



Source: Arthur D. Little analysis

Use of street lighting to monitor traffic flows can help to collect data about how people move, and the related patterns can influence driving mobility solutions and improve products such as parking guidance (real-time parking availability information and rates through other devices), parking enforcement (detection and reporting of payment, no-parking zones, optimum routes for enforcement officers), traffic monitoring and route planning.

Some use cases are found below.

Figure 22: Smart mobility examples

Traffic flow monitoring

- Traffic flow monitoring solutions provide data and analysis to help traffic managers, road maintenance contractors and even road users make informed judgements and better decisions. By leveraging the current network infrastructure it is possible to collect a wide intelligence on traffic volume, type, speed, directional flow, and driver behavioral patterns

Public alerts

32 LPs - *100+spaces*

- Cleverciti Systems GmbH has won the tender for detecting Taxi ranks in the City of Westminster, detecting 100+ spaces across 32 different lamp post sensors

City of Westminster | Cleverciti

Source: Clearview Website, Cleverciti Website, Arthur D. Little analysis

Connectivity provision

The new "smart pole" allows wireless carriers to quickly and easily densify their networks. In this case the pole will provide value-added services such as:

- Public/private wi-fi to local municipalities/dense urban areas through full fixed broadband connectivity (fiber).
- From just colocation to whole fiber connected radio base station to mobile/integrated telcos in order to increase capacity in urban areas, data offload and 5G microwave networks.

Therefore, the smart pole could be an important asset in 5G growth.

5G market: The first commercial launches were in Korea and the US in the first half of 2019. In five years global 5G subscribers are expected to reach 1 billion; 12 percent of all mobile subscriptions and 20 percent of mobile data traffic will be concentrated on this network.

Small cells: With 5G, small-cells demand will increase because, when network upgrades are no longer sufficient to support the increased traffic, operators will need to build new small cells. This demand growth will be remarkable in areas with IoT and smart city services, but weaker in other areas.

Light poles: Considering their distribution, light poles could be used to arrange small cells.

Some use cases can be found below.

Figure 23: Connectivity provision examples

DAS wireless services

2,500$ LP/year - *10 years agreements*

- Installation of distributed antenna system or systems, small cell facilities, and any other applications and configurations to deliver Verizon services

CITY of BOSTON | verizon

4G LTE wireless technology

100 LPs

- Smart poles with fiber backhaul, equipped with Ericsson 4G LTE small cell technology, increase capacity for network service providers

LOS ANGELES | PHILIPS ERICSSON

Source: Arthur D. Little analysis

The connected car is one of the most interesting applications for 5G, as its features of reliability, latency, peak data rate and number of connected devices allow it to deploy the most advanced use cases, as highlighted in Figure 24.

Profitable business models still have to be defined and consolidated in order to maximize the benefits for all stakeholders involved. Different models have been observed around the world (revenue sharing, pure asset renting, partnership, etc.) but current price references still seem too high for large scaling application; this being an opportunity both for connectivity providers but also at the same time the asset owners.

Figure 24: The connected car

Current

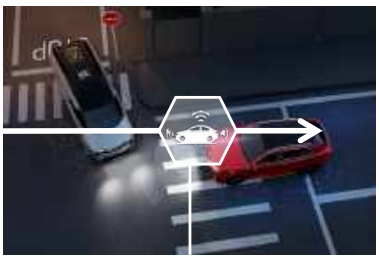
- On demand GPS map data
- Over-the-air software updates
- Assisted driving
- Traffic jam warnings
- Connectivity within the vehicle
- Real-time driver statistics
- Personalized insurance services on driving behavior

On the road to 5G

- Predictive maintenance of vehicle
- Intelligent navigation: sensor data for real-time traffic, computed with data from other vehicles, weather, road authorities, cameras and radars, etc.
- Vehicle-to-vehicle communication
- High-speed internet access
- Semi-auto pilot driving

5G experience (2021)

- Cooperative collision avoidance
- Vulnerable road user discovery
- Advanced infotainment (e.g. 4K streaming, online gaming in the car)
- Ancillary services such as virtual presence
- Autonomous vehicle control



Source: Arthur D. Little analysis-Ericsson study

3. Key takeaways and recommendations

Lighting poles represent **strategic infrastructure** for smart city development, thanks to their capillarity, connectivity and electrification. In particular:

- Poles' capillarity is extremely relevant for **video surveillance** services and **autonomous driving**.
- Poles are the most convenient infrastructure on which to host a fiber network, and they can also be used for hosting small cells/antennas to meet **5G densification** requirements.
- Poles are already equipped with electricity connection, and can host **EV charging** points with relevant cost benefits compared to traditional low-charge EV stations.

We observed a significant number of pilots emerging across countries, but a lack of large-scale deployment. The main constraints can be summarized as follows:

- Smart cities are still in an ***emerging phase*** and typically have gestation periods of 10–15 years before realizing their full GDP potential[1].
- Demand for smart city services is not yet sufficiently developed: **players must create the need** (e.g., as occurred for smart phones).
- The **first buyer of smart cities is the public administration**, which typically experiences financial constraints and lack of technical expertise:
  - Players must engage the Public sector by designing a solution instead of trying to sell a product (e.g., using the project financing tool).
  - Smart city solutions that enable cost efficiency are more likely to be pursued by municipalities (e.g., LED replacement is widely adopted in larger cities).
- **Business models are not clearly defined** and differ from one city to another. No smart city model can be observed universally.
- Several stakeholders are present and need to find the right way to collaborate.

We recommend four steps for players which aim to grow in the smart city market:

1. **Map stakeholders and regulatory context:**
   - Map all stakeholders by sector and role (e.g., buyers versus regulators).
   - Understand the regulatory framework and procurement processes.
2. **Prioritize and understand:**
   - Cluster stakeholders (e.g., public versus private, central versus local administration, buyers versus institutional, territorial reach) and prioritize based on a panel of key drivers (e.g., spending, smart maturity index, utilities' presence in the municipality).
   - Understand their priorities and how smart services can address them.
   - Set different rules for engagement.
3. **Define the business model and set up strategic alliances:**
   - Understand own KSF and set up partnerships.
   - Define the target position along the value chain (including offering a portfolio).
   - Differentiate the positioning according to different types of municipalities (big versus small, mature versus immature, presence or not of a public utility owned by the municipality).
4. **Engage and monitor:**
   - Identify the target areas.
   - Proactively engage key buyers (e.g., leveraging of project financing instrument).
   - Effective institutional communication and lobby activities.
   - Monitor performance and identify areas of improvement.

Authors

Saverio Caldani, Irene Macchiarelli, Andrea Romboli, Vincenzo Ippolito

www.adl.com/StreetLighting

1 Cisco estimates smart cities to have a GDP impact of 15 percent from a benchmark of 600 connected cities across the world

The future of hydrogen and e-fuels

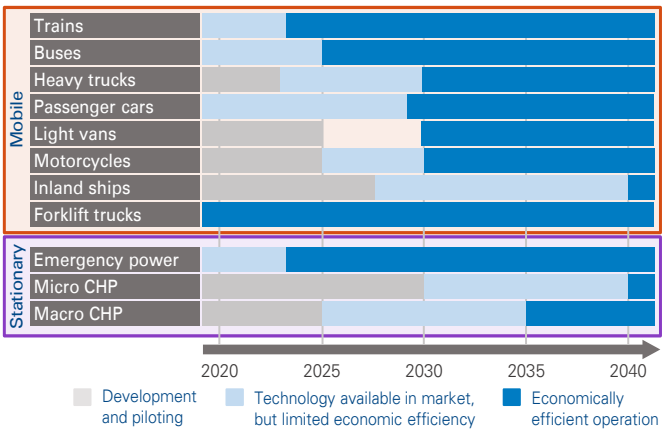
Will hydrogen be the new oil?

With intensified discussions to become carbon-free, hydrogen is back at the top of the agenda for some. Others see it as over-hyped with too many limitations, especially with regard to efficiency. Similarly, e-fuels[1] are controversial. Thus, while battery electric vehicles are starting to take off, the future of hydrogen and e-fuels is very much in question. But now players, ranging from nations, corporations, and energy and utility enterprises to start-ups, need to place their bets on the future energy carrier that will replace fossil energy. Based on plans for a carbon-neutral economy in 2050[2], we want to introduce a holistic framework to assess the real potential of hydrogen and e-fuels.

ADL Delphi study on the future of hydrogen

New energy solutions need to form a sustainable, CO_2-neutral economy in Europe and across the world. Hydrogen might be one of them, but its application and role are highly uncertain. That role is of the highest strategic relevance because it determines future business models, investments, and the characteristics and sustainability of the overall energy and industrial system. To gain insight into that, we conducted a study on the future of hydrogen applications. Energy and application experts have seen varying maturity, as shown below.

Technology maturity and economic efficiency of major hydrogen applications



Source: Arthur D. Little

In some areas hydrogen application is already mature and in commercial use (e.g., forklifts), while other sectors are in market upscaling (e.g., passenger cars) or market entry (e.g., trucks). In general, experts in industry and research expect the wide-scale usage of green[3] hydrogen within decades.

They also estimate that up to 2030, mobile applications covering trains, trucks and buses will provide the highest growth potential. Hydrogen's higher energy density and lower specific weight are assets in these applications. The market penetration of stationary applications such as heating (CHP[4]) is initially limited because more cost-effective means of decarbonization are preferred (e.g., energy savings and heat pumps), and the lack of hydrogen pipelines makes stationary applications difficult to realize.

Introducing a holistic view

In our Delphi study, as well as through following public discussion, we found that the view of hydrogen tended to be binary. Hydrogen is either seen as the sole long-term option for a CO_2-neutral economy or rated as unsuitable and flawed. Electric and battery electric applications are supposedly much better for many reasons, mainly their much higher efficiency. Although this view appears to be comprehensive at first glance, it is really rather one-eyed. Hydrogen-related studies too

[1] Fuels produced from renewable energy (e.g., solar, wind power)
[2] Carbon neutral often means a net CO_2 reduction by 95 percent compared to 1990
[3] Hydrogen generated from renewable energy
[4] Combined heat and power

often set one important but unrealistic assumption, often only implicitly: clean electricity is available at the exact amount, when and where needed. While this may hold for some countries, it seems unrealistic in the foreseeable future for large economies such as China, the US, India, and Germany. Without this assumption, elementary questions arise around, for example, the origin of energy and electricity.

A holistic view is needed instead. On the energy side, this view differentiates between energy production efficiency ("upstream"), which is specific for each country, and consumption efficiency ("downstream"), which is specific to each application.

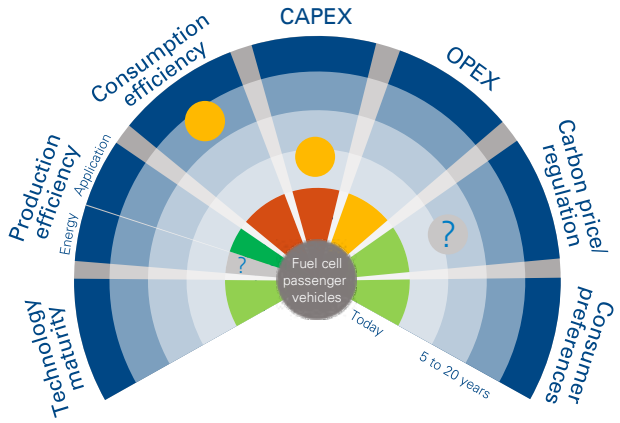
Definition of dimensions

Technology maturity	Maturity of technology from developing to commercial availability
Production efficiency	Energy production efficiency from power generation to consumer & application production efficiency including maintenance and recycling
Consumption efficiency	Energy efficiency during consumption from intake of energy to heat or movement
CAPEX	Cost of application to produce and install, including incentives and recycling
OPEX	Cost of application to run, including infrastructure, taxes and duties
Regulation/ carbon price	Governmental actions to prohibit, restrict or enhance certain applications or behaviors
Consumer preferences	Degree to which consumers are willing to pay for certain characteristics

Source: Arthur D. Little

As a first approach to the holistic view, we have identified seven relevant dimensions to compare CO_2-neutral alternatives. (See the above figure.) This model can be applied to assess hydrogen, battery electric, and e-fuels in general, for specific applications or holistically. (See the below figure.) To illustrate, we explain the dimensions with the example of fuel cell electric (passenger) vehicles (FCEVs), which are powered by hydrogen.

Holistic assessment model with hydrogen passenger vehicle as an example



Positioning compared to BEV: Better Equally Worse

Source: Arthur D. Little

A holistic view of passenger vehicles

Both FCEVs and battery electric vehicles (BEVs) are commercially available and thus technologically mature. For application production efficiency, BEVs have higher energy demand in production, which is offset earlier or later in a vehicle's lifetime, mainly depending on battery size. For energy production efficiency (upstream) we need to consider where the energy comes from.

For simplicity, we compare two scenarios: First, 100 percent local green energy, and second, imports of green energy from the Middle East.

As shown below, locally produced hydrogen is much less efficient than local green electricity. But when energy is imported from, for example, the Middle East, hydrogen's efficiency roughly doubles of that of electricity.

Upstream electricity scenarios

Scenario I	100% Local green electricity	Electrolysis & H_2 transport ~45% loss	Hydrogen at fueling station	~55% efficiency
		Transportation ~5% loss	Electricity at charging station	~95% efficiency
Scenario II	100% Solar park in Middle East	Electrolysis & H_2 transport ~50% loss	Hydrogen at fueling station	~50% efficiency
		Electrolysis, H_2 transport, electricity production & transport ~75% loss	Electricity at charging station	~25% efficiency

Source: Arthur D. Little

FCEV consumption efficiency is around 60 percent, much lower than that of BEVs. CAPEX is decreasing for both BEVs and FCEVs as production scales – which is, for now, an advantage for BEVs. For OPEX, it can be expected that the purchasing price of electricity will be lower than that of hydrogen (at least for private chargers), but hydrogen prices will stay within reasonable limits so non-electrifiable applications can become CO_2 neutral. This suggests that OPEX will likely be lower for BEVs. Current EU regulation favors FCEVs and BEVs to the same degree, and both will benefit over fossil-based fuels with tightening regulation. In general, FCEVs are suited to consumer preferences because they have many similarities to combustion engines (short refueling, long ranges). On the other hand, consumers might get accustomed to BEVs and their advantages (refueling at home, acceptance of low ranges, more availability of charging stations).

Overall, assessment of battery electric and, e.g., hydrogen, depend on the specific requirements of the application, such as range and payload, as well as consumption efficiency. The often-overlooked decisive factor is the source of energy and related energy production efficiency.

For passenger cars we conclude:

1. From an application and energy consumption point of view, BEVs are favorable for lighter vehicles with lower range requirements, while hydrogen and e-fuels are better for heavier vehicles with high-payload and long range requirements.
2. From an energy production point of view, BEVs are favorable if clean electricity is regionally available all year.

Trucks and buses

Heavy-duty trucks and buses will benefit from hydrogen, especially in long-distance traffic: high reliability and lifetime mileage that is comparable to or even exceeds diesel engines, ranges of up to 1,300 km, and refueling times of seven to 12 minutes. Currently, the major downside of hydrogen trucks is high investment costs, which significantly exceed those of diesel trucks. However, up to 2030, costs will decrease by more than 50 percent, beating diesel engines in operational costs.

In the local public bus segment, hydrogen is in strong competition with batteries. Economically attractive operation of hydrogen buses is estimated to be reached in 2025, when hydrogen electric (HE) and battery electric (BE) buses will be equal in total cost of ownership.

E-fuel assessment

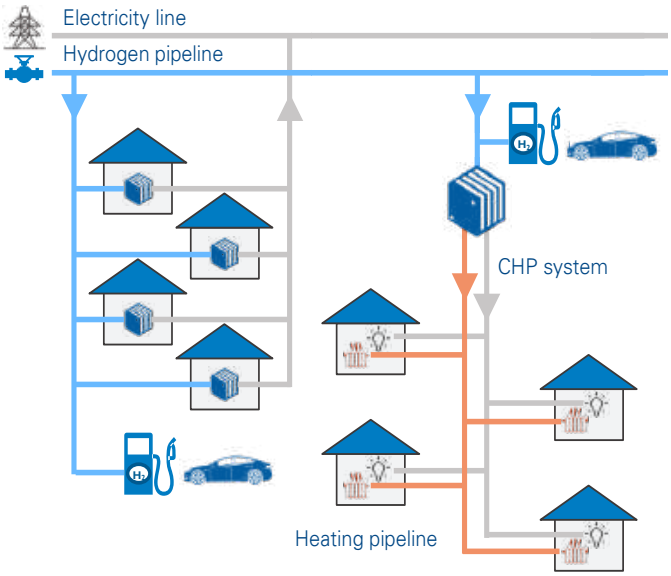
Compared with hydrogen and electricity, e-fuels have an advantage with transportation and storage. Thus, their very low energy efficiency becomes irrelevant when e-fuels are generated from power that is excessively and cheaply available and would be lost otherwise (such as in very remote places with lots of clean energy), and that can be much more easily transported to where it is needed. Although e-fuels burn much more cleanly than fossil fuels, only hydrogen and battery electric vehicles are locally 100 percent clean.

Buildings

Combined heat and power (CHP) fuel cells provide electricity and heating for buildings and entire urban districts. The fuel cell itself is already widely available in the market, but used with hydrogen converted from natural gas. While the overall process is highly efficient, a CO_2-neutral operation is only possible with green hydrogen. The CHP solution can be implemented in two approaches. (See the below figure.) Micro CHP serves smaller apartment buildings with dedicated hydrogen connections. Macro CHP supplies larger buildings or even whole urban districts. Whereas the CHP system itself requires a hydrogen pipeline, the "last mile" of the network can consist of simpler and more cost-efficient district heating pipes and standard electricity lines.

Already today, hydrogen can be fed into the natural gas network up to 10 percent – soon to be 20 percent. A long-term perspective involves a fuel switch from natural gas to hydrogen for whole cities, or even whole countries. This, however, will require a large-scale hydrogen supply. Other heat decarbonization options, such as power-to-heat, solar heat and insulation, are more realistic.

Hydrogen concept for buildings



Source: Arthur D. Little

Industrial feedstock

To reach the 95 percent CO_2 reduction target, almost all carbon fuels would need to be eliminated. Consequently, current fuels would need to be replaced by wind, solar and nuclear power, as well as (power-based) hydrogen and e-fuels. The only option to use coal, oil or natural gas would be underground carbon capture and storage (CCS), a technology that is not yet proven for the long term, but could be an intermediate solution. Most of the feedstock in the chemical, metal and cement industries relies on carbon energy sources. Feedstocks, as well as the high-temperature burners needed by these industries, could not be replaced by electric power – only by hydrogen and e-fuels. The sheer volume of feedstock would push hydrogen demand to enormous dimensions. Replacing Europe's selected chemical H_2 feedstock with green hydrogen and e-fuels would require 1.5 times Europe's renewable energy potential[5], which would leave no hydrogen for any other sector!

Given the scale sensitivity of current electrolyzer technologies, larger-scale projects secured by industrial off-takers are expected to be among the driving forces in the hydrogen economy.

[5] DECHEMA (2017)

Hydrogen production and infrastructure

To fulfill the huge demand for hydrogen, production and transmission infrastructure are the key success factors. For example, studies expect that by 2050, Germany's primary energy consumption will be 10 percent (156 TWh) hydrogen and 28 percent (442 TWh) e-fuels[6]. Due to high transportation costs, hydrogen is produced as locally as possible.

But there are also conceivable scenarios (including concrete projects) in which green hydrogen is shipped from low-energy-cost countries – similarly to LNG.

E-fuels will play an important role in industries in which neither electrification nor hydrogen can be easily applied, e.g., aviation, and will be mainly imported from non-EU countries due to limited green energy sources. Therefore, Europe must invest in green hydrogen and e-fuel sources from other continents in the long term. The foundation for a global hydrogen supply chain must be created now. Hydrogen production in regions rich in solar and wind, such as North Africa, the Middle East, and North America, would provide not only the required capacity, but also more favorable renewable cost conditions. Chemical, steel and other energy-intensive industries need be reliable foundations for investments in their existing and future plants today, given their 40-plus-year investment horizon.

Politics is now called upon to create the appropriate setting: optimal regulatory conditions, a clear and solid perspective of the carbon price, and a global carbon pricing mechanism which prevents "carbon leakage" into other countries.

Key take-aways

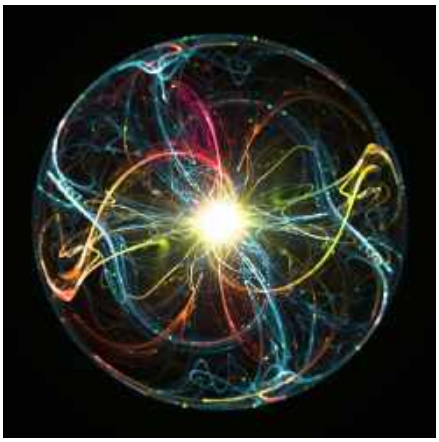
1. Within mobility, hydrogen and e-fuels will play the biggest role for heavy trucks.
2. Replacing natural gas with feedstock and industrial heat will create a demand for hydrogen, which will exceed Europe's green energy potential by 50 percent.
3. Importing hydrogen and e-fuels will play a key role in the future for nations with limited permanent green energy sources and unclear nuclear strategies.
4. When hydrogen and e-fuels are imported, FCEVs and e-fuel-run combustion engine vehicles tend to become more favorable.
5. Thus, a holistic perspective on energy applications is needed.

Authors

Christian Adolph, Dr. Matthias von Bechtolsheim, Roman Mathyssek, Dr. Klaus Schmitz, Dietrich von Trotha

www.adl.com/HydrogenAndE-fuels

[6] dena/ewi (2018)



Navigating the energy transition

How energy companies are shaping their future

Arthur D. Little's "Energy & Convergence" Report

Arthur D. Little

Arthur D. Little has been at the forefront of innovation since 1886. We are an acknowledged thought leader in linking strategy, innovation and transformation in technology-intensive and converging industries. We navigate our clients through changing business ecosystems to uncover new growth opportunities. We enable our clients to build innovation capabilities and transform their organizations.

Our consultants have strong practical industry experience combined with excellent knowledge of key trends and dynamics. ADL is present in the most important business centers around the world. We are proud to serve most of the Fortune 1000 companies, in addition to other leading firms and public sector organizations.

For further information please visit **www.adlittle.com** or **www.adl.com**.

www.adl.com/Energy&Convergence