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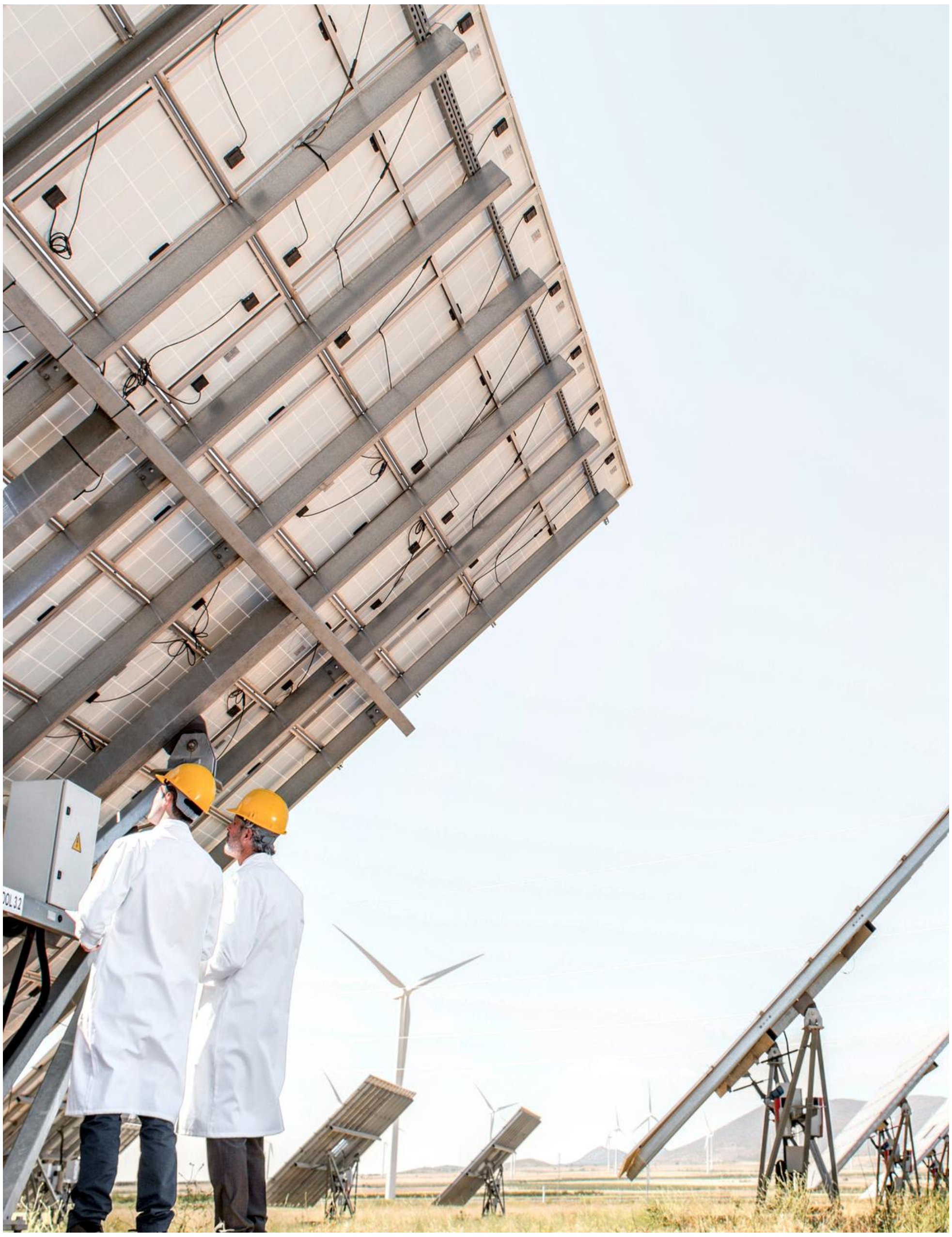

Infrastructure investments play an important role in the current global energy transition.

As technology and consumer behavior continue to evolve, how should infrastructure investors position their investments?

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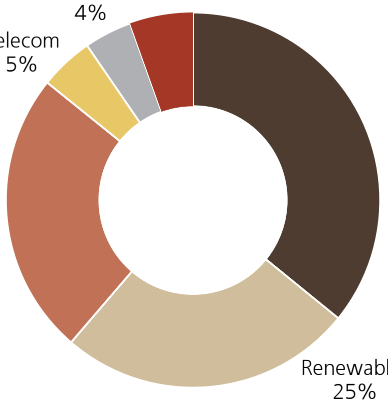
Energy transition and global infrastructure

In the past decade, improving technology and shifting consumer behavior has transformed the energy landscape. The next decade could bring even greater change as the conventional generation model faces unprecedented challenges from a combination of changing consumer perceptions, renewables, storage and an abundance of cheap gas. In this paper we set out the secular changes in the industry and how this can impact infrastructure investments.

Executive summary

Technological disruptions in the global energy sector have led to new challenges and opportunities for infrastructure investors. Given that this sector dominates private infrastructure markets, investors must have a good understanding of these secular changes in order to invest successfully. In 2017, investments in the energy (including power and midstream) and renewables sector accounted for over 60% of private infrastructure transactions worldwide (see Figure 1).

Figure 1: 2017 Global private infrastructure transactions by sector



Source: Inframation, August 2018

In our view, there are four key changes that have impacted the energy industry this past decade:

- Significant cost reduction has led to the rapid expansion of renewable energy capacity
- Rising popularity of electric vehicles and falling battery costs have opened up the potential for energy storage solutions
- Increasing awareness of environmental issues and global warming have changed consumer preferences
- Fracking has made the U.S. an exporter of hydrocarbons and one of the world's lower cost producers

These factors have changed the fundamental principles of energy investments. The installed capacity of renewables has considerably exceeded even the most ambitious forecasts. This will create new opportunities and challenges around the need for capacity to balance the grid, given the intermittent nature of renewable energy. The rise of distributed renewable energy and electric vehicles also requires new smart grid and charging infrastructure. This would allow the existing system to incorporate these new sources and uses of power.

In the short to medium term, the natural choice for balancing the power system is natural gas, a case that is further strengthened by the abundance of cheap gas due to the shale revolution. In the longer term, with significant reductions in the cost of batteries, there is also potential for renewables with energy storage capacity to replace baseload generation, although timing is less certain.

The rise of U.S. shale will also open up other investment opportunities across the global hydrocarbon supply chain, as midstream investments have lagged behind the growth potential and export ambitions of the upstream shale industry.

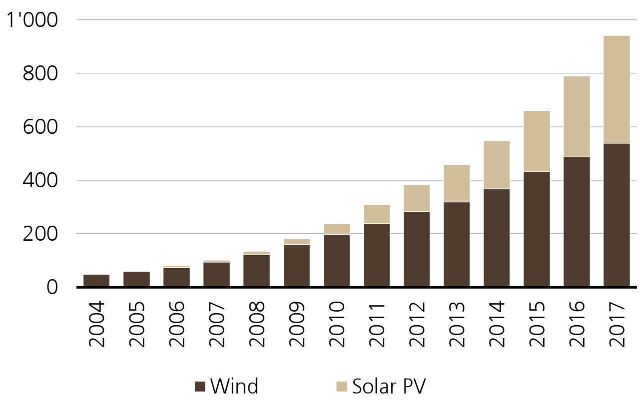
When evaluating these secular trends, it is important to bear one common feature in mind: markets have continuously underestimated them.

Key secular trends

Over the past decade, disruptions to the energy sector can be explained by improving technology, rising environmental awareness, and broad political support. Together, they have changed the way we produce and consume energy. Below, we highlight four of these new developments.

Rapid expansion of renewable energy resources
Over the past decade, technological advances and manufacturing improvements have driven costs lower for renewable energy, which combined with generous subsidies around the world, has led to a rapid expansion in capacity. According to REN2[1], non-hydro renewables increased from 3.3% of global electricity generation in 2010 to 10.1% in 2017. Wind and solar in particular saw their global capacity increase nine-fold in the past decade (see Figure 2), taking share away from conventional power generation such as coal and nuclear.

Figure 2: Global wind and solar installed capacity (GW)



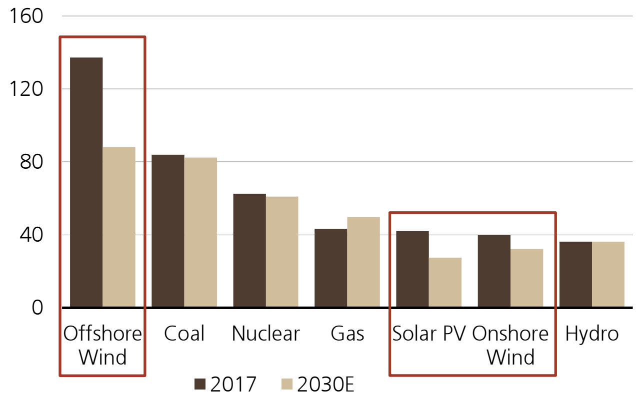
Source: REN21, June 2018

[1] Renewable Energy Policy Network for the 21st Century

If we look at the levelized cost of electricity (LCOE[2]), utility-scale solar and onshore wind projects have seen 86% and 67% LCOE declines since 2009, according to the Lazard Levelized Cost of Energy Analysis 11.0. IRENA[3] argues that the share of renewables in the world's energy mix can potentially increase to 36% by 2030, double 2014 levels.

While it is difficult to estimate how much renewables capacity will be added in the next decade, it is clear that the current trend will remain in place – renewable costs will continue to decline and capacity will continue to expand, even as subsidies phase out. NREL[4] estimates that wind and solar costs could fall another 20-40% between now and 2030 (see Figure 3). This should offset near term headwinds such as falling subsidies and trade tariffs, and ensure that renewables will continue to gain share from higher cost conventional power generation.

Figure 3: 2030E vs. 2017 average levelized cost of electricity (USD/MWh)



Source: NREL, July 2018

In particular, offshore wind is the most recent technology to follow this trend, and is expected to see the most significant cost improvements in the coming decade, albeit from a high base. This year, Netherlands and Germany awarded their first subsidy-free offshore wind projects. Although the sector is still in its infancy in the U.S. and Asia, the U.S. has just completed its first offshore wind auction ever.

[2] LCOE is a metric within the power industry to compare all-in project costs of different types of power generation on an apples-to-apples basis
[3] International Renewable Energy Agency
[4] National Renewable Energy Laboratory

Falling battery costs and the rise of electric vehicles
One limitation of renewable energy is its intermittency, as solar and wind resources are unpredictable. This creates a barrier to the percentage of renewables in the energy system as peaking or baseload generation capacity needs to be on standby in the event that production is lower than forecast. This is why energy storage or batteries are often referred to as the "holy grail" for renewables, as it solves this intermittency problem. For example, when demand is low in warmer and windier climates, a solar or wind farm can charge its on-site batteries and release this energy later when demand picks up, thus smoothing out its power output.

Further down the value chain, grid operators can also use batteries to increase grid reliability while deferring larger transmission and distribution (T&D) upgrades. On the consumer level, end users can also use batteries to supplement the electricity that they purchase from the grid, especially if they already have rooftop solar panels installed.

Currently, batteries are still too expensive in most regions around the world, but like renewables, this is changing rapidly. Battery costs have fallen ~80% in less than a decade, and IRENA expects it to fall another ~50-60% by 2030. At lower costs, batteries will first disrupt inefficient fossil-fuel peaker plants (a type of power plant that operates in short time periods during periods of demand spikes), and longer term, it will also disrupt base load generation like coal, nuclear, and also less efficient gas plants. IRENA expects global battery capacity to grow ~20% p.a. during this period.

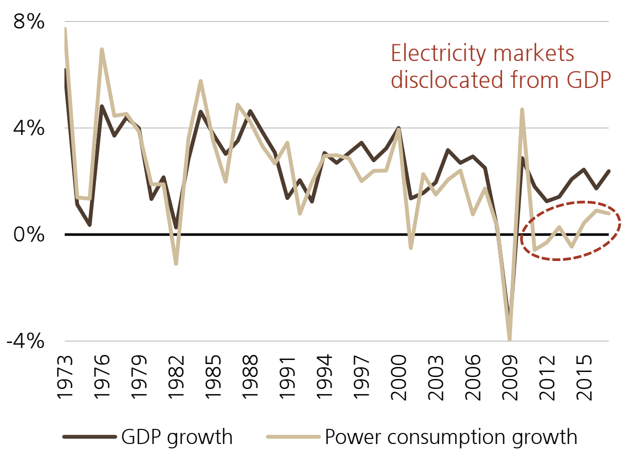
Interestingly, the battery industry is intimately tied to the automotive sector. The success of Tesla has propelled electric vehicles ("EVs") into the mainstream, and showed that consumers have finally voted on EVs with their own wallets. Companies like BP, Shell, McKinsey, DNV GL, and Wood Mackenzie all expect global fuel or gasoline demand from transports to peak at around 2030, as EVs continue to take share. More importantly for energy investors, the growing EV ecosystem has increased battery manufacturing economies of scale and R&D, which inadvertently benefits the power sector.

Many countries have already announced aggressive targets to phase out vehicles with Internal Combustion Engines (ICE). Norway said that it will ban ICE cars by 2025, Germany, India, Ireland and Netherlands by 2030, and the United Kingdom and France by 2040. China, the largest automotive market in the world, said they would ban ICE vehicles in the near future.

The growing global EV ecosystem should continue to push down battery costs, especially in Asia where battery suppliers are experimenting with newer chemistry content and form factors. This opens up opportunities for infrastructure investors that we will discuss later.

Changing consumer behavior driving supportive policies and improving energy efficiency
The global energy transition is not just a story about the changing energy mix. It is also about changing consumer preference and supportive government and institutional policies, which have driven many energy efficiency initiatives. For a long time, electricity markets have been a good proxy to overall economic activity. However, this relationship has broken down since the financial crisis in 2008, as energy intensity has fallen globally. For example, OECD power demand growth has broadly matched GDP growth rates before 2008. Since then, power demand growth has been flat, even though GDP growth averaged ~2% (see Figure 4).

Figure 4: OECD GDP vs. power consumption growth



Source: World Bank; OECD; IEA, September 2018

The declining energy intensity is due to the shift away from heavy manufacturing and the increase in energy efficiency at the average household, especially in mature markets. Even a developing country like China saw its energy intensity fall by 30% between 2009 and 2017, as the economy transitions away from heavy industries.

These shifts are both demand and policy driven, as rising environmental awareness has led to the enactment of supportive policies. On a global level, the Kyoto Protocol (commitment periods from 2008-2020) and the Paris Agreement (covers period from 2020 onwards) are reflective of the worldwide commitment to these causes. On a country level, we have already discussed the generous renewable subsidies and the aggressive EV targets. Furthermore, the U.S. and EU started restricting the use of incandescent light bulbs in 2007 and 2009 respectively, which led to the growth of energy efficient LED light bulbs and energy efficiency gains.

Green policies extend beyond just governments, as investors and employees of corporations are also demanding greater environmental responsibility. In recent years, there has been an increasing focus on carbon-neutral targets for corporates, with many large U.S. companies signing long term commitments to renewable energy by signing power-purchase agreements (PPA). Oil majors like BP and Shell have also made small investments into the renewable energy space – a sign of the changing times.

Some argue that the adoption of EVs is a silver lining for power demand, as it offsets the current declines. However, transportation only accounts for a very small percentage of overall electricity consumption, thus limiting the impact of EVs despite the rapid growth. For example, the IEA[5] expects the global EV fleet to grow ~30% p.a. through 2030 to ~125 million (see Figure 5). This leads to ~400TWh of power demand from EVs, which is just 1.5% of the ~26,500TWh of global power generation in 2017, or ~0.1% p.a. incremental demand between now and 2030 – better than zero, but hardly a panacea to a struggling industry. We can also look at the example of Norway, whose EV market share increased from 6% of new car sales in 2013 to 39% in 2017. Yet power demand over this period only increased ~0.5% per annum.

Power demand is facing more headwinds than tailwinds in mature markets, and it appears that there is still plenty of capacity for further energy efficiency improvements globally for years to come. Although demand in emerging markets should remain strong, BP estimates that global energy intensity will still decline 2% p.a. in the next two decades, as energy efficiency improves around the world.

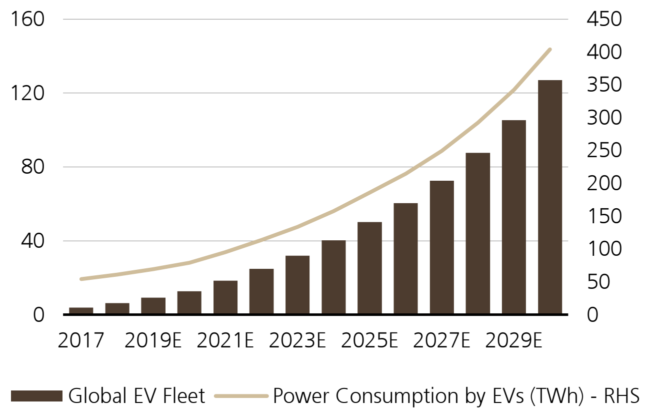
Growth of U.S. shale oil and gas

The global energy transition is very much a story about green initiatives on both the supply and demand side, but interestingly, the oil and gas sector has also undergone its own transformation during this time.

In our view, it will likely take at least another decade for renewables plus battery costs to come down enough to completely replace fossil fuels. In the interim, natural gas will continue to present opportunities for infrastructure investors. Until batteries become economically viable, gas will be needed to support renewable developments. Gas is often referred to as a "transition fuel" as it is less carbon intensive and more efficient than other fuels such as coal and oil, and will remain an important source of energy over the next decade.

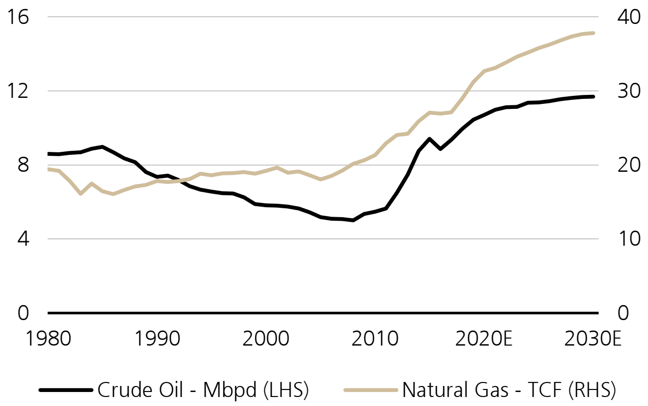
One of the most important developments in the oil and gas industry is the improvement in horizontal drilling and hydraulic fracturing (also known as fracking), especially in the U.S. Energy companies have learned to stimulate shale formations by injecting high pressure fluids into wells, thus unlocking hydrocarbons that were previously trapped and uneconomic to extract. Within the last 10 years, U.S. crude oil production has reversed its multi-year secular decline, and is now expected to grow ~2% p.a. in the next 10 years according to the U.S. Energy Information Administration (EIA) (see Figure 6), driven by the Permian basin in Texas. Similarly, natural gas production is expected to grow ~3% p.a.

Figure 5: Global EV fleet and EV power consumption



Source: IEA, May 2018

Figure 6: U.S. crude oil and natural gas production

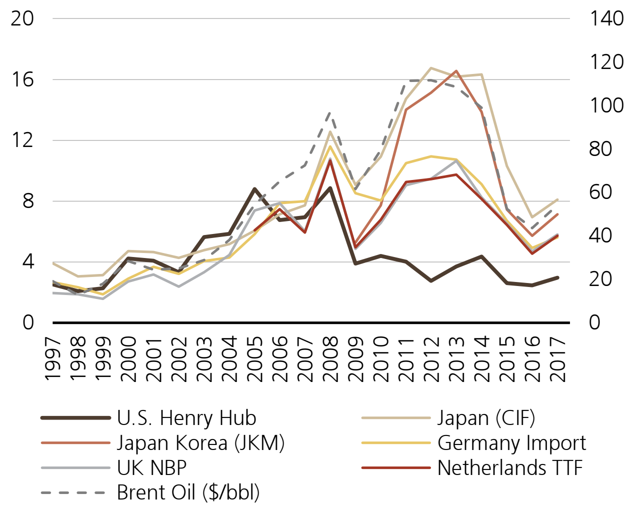


Source: EIA, February 2018

[5] International Energy Agency

Natural gas production is expected to grow faster than oil, as many oil wells produce natural gas as by-products known as "associated gas". This means in the U.S., high oil prices lead to lower gas prices, as producers are encouraged to extract this free gas from oil wells. The abundance of cheap shale gas from the hydraulic fracturing has pushed U.S. natural gas prices down from ~USD 13/MMBtu in 2005 to ~USD 3/MMBtu by 2009. U.S. natural gas is currently among the cheapest in the world, since gas prices at other regions broadly track Brent crude oil price (see Figure 7), while U.S. gas price now has negative correlation to oil due to the supply of associated gas.

Figure 7: Global gas (USD/MMBtu) **and oil price** (USD/bbl)



Source: BP; Thomson Reuters Datastream, June 1018

This has opened up the export markets for U.S. producers via pipelines to Mexico and Canada, or in the form of Liquefied natural gas (LNG) that is shipped around the world. Demand for LNG has increased globally in the past decade with rising environmental awareness. China, for example, has become an important source of demand, as it shifts away from coal to natural gas to combat pollution. Finally, there is also political desire for some countries to diversify away from traditional gas suppliers such as Russia or Qatar, which makes U.S. LNG more desirable despite its higher costs.

Aside from natural gas, the U.S. shale boom has also allowed the U.S. to increase its exports of other hydrocarbons. For example, the U.S. lifted its crude export ban at the end of 2015, leading to its first export of crude oil in decades. Gasoline exports are also rising as domestic consumption faces headwinds (e.g. EVs, fuel economy regulation), while low-sulfur fuel exports should increase with new IMO 2020 rules limiting the use of high-sulfur fuels in international shipping (U.S. refiners are more equipped to produce these fuels than international counterparts). Finally, U.S. natural gas and natural gas liquids (NGLs, produced from both oil and gas wells) are processed into chemicals like polyethylene, methanol and ammonia, which can also be exported.

Impact for infrastructure investors

Based on the four key disruptive forces that we have highlighted, we discuss what it all means for infrastructure investors. As energy sector dynamics can vary significantly across regions, we set out our high-level views.

Power and renewables
The growth of renewables has been a positive for infrastructure investors with most investors having at least some exposure to the asset class whose popularity has been further boosted by ESG features. The solar and onshore wind sectors are now mature asset classes, with equity returns for well-structured projects having compressed significantly in recent years and now typically trading in single digits.

The trend of renewables moving towards parity with conventional generation is positive for future renewable developments. However, investors will need to gain more comfort in merchant project economics, as renewables incentives and subsidies will undoubtedly phase out once parity is reached. Even in subsidized regimes, investors seeking higher returns will also need to take on more power price or counterparty risk, as yields continue to compress.

Despite the growing importance of renewables, some conventional power projects remain attractive. Given natural gas will remain an important "transition fuel", gas-fired power stations operating in favorable markets should remain attractive to infrastructure investors. In the U.S., the EIA still expects the gas-fired power fleet to grow 1% p.a. until 2030. In Europe, an Aurora Energy Research study commissioned by UBS estimates that battery costs will still need to fall 80% in order to fully replace gas-fired power generation.

The rapidly evolving power generation fleet has also created new challenges for the grid. It has led to congestion in areas such as Texas and Germany, where there is insufficient transmission capacity to bring the abundant yet remotely located energy supply to the more densely populated load centers. This means energy is either wasted or is sold at significant discounts to benchmark prices. However, this also opens up potential investment opportunities in T&D networks.

Energy storage, grid and charging infrastructure
There are a number of specialist investors actively looking at utility-scale batteries. The price trajectory has followed the LCOE for renewable energy, which means costs will keep falling and adoption will continue to rise. In some areas, utility-scale energy storage projects are able to secure long term power purchase agreements (PPA) with high quality utility counterparties. However, these opportunities are limited and will not be a near-term driver of battery adoption on a global scale, until battery costs decline more dramatically (which will eventually happen).

Alternatively, some energy storage projects have relied on the need for rapid response services by grid operators. In the UK, a battery solution was selected to enhance frequency response services to National Grid (see case study). However, the opportunity for such high quality revenues sources is somewhat limited. Similarly in the U.S., some battery projects have over-relied on revenues from frequency regulation, an opportunity that became more limited as certain markets became saturated.

In order to make such assets more financeable, owners should now look to create multiple revenues sources longer term, commonly referred to as "stacking". This means they should try to generate multiple revenue streams, which could involve a combination of capacity or reliability payments, the monetization of T&D upgrade deferrals, or other ancillary services. The regulatory framework for these revenue streams is still a work-in-progress in most regions around the world, but is something we should continue monitoring.

The interest in batteries is not exclusively for specialist investors. Owners of wind and solar assets are increasingly looking at the benefit of adding on site batteries to smooth the dispatch profile and take advantage of spikes in demand, or offset the negative impact from grid congestion issues. Keep in mind that longer term, any price arbitrage opportunities should theoretically disappear as storage becomes more commonplace. However, with continued falling costs, renewables plus batteries should inevitably take share away from all forms of conventional power generation. We previously discussed that it will likely be at least a decade before this happens as costs must decrease further. Some regions with strong political backing (e.g. California) will likely see disruption sooner rather than later.

Another way investors can participate in rising energy storage and electric vehicles is through grid investments. Historically, the grid is a "one-way" street where power is transmitted from power stations to load centers. With the rising popularity of distributed renewables and energy storage (including EVs), more advanced equipment such as smart meters or smart grids are needed to incorporate these new sources of energy, where households and distributed energy suppliers can monitor their own electricity output and consumption, share data with other parts of the grid, and sell excess electricity into the network, ensuring flexibility and reliability of the entire system. On the other hand, traditional grid infrastructure that operates in areas with growing distributed renewables may face some challenges, as customers will purchase less electricity from the grid as distributed resources grow.

Finally, EV charging is another niche area that will create opportunities in the future. At present, opportunities are on the smaller-end of the scale, and the return is highly dependent on the EV adoption curve – potentially not a risk that traditional investor may be comfortable taking. Given the scale of the CapEx requirement, we would expect the rollout of EVs and associated smart infrastructure to benefit from some form of regulated or PPP (P3) framework potentially in a smart-city type solution, to support the ambitious EV rollout plans across many countries. However, rapidly evolving EV charging technologies may also present obsolescence risk that investors will need to consider.

Case Study: U.K. National Grid and Energy Storage
The U.K National Grid currently has 500MW of utility-scale energy storage capacity in its pipeline, some of which is already operational. One big advantage of batteries are their rapid start times, taking only seconds (or less) to release electricity versus conventional peaking plants (i.e. gas or oil) that typically take a least 10 minutes to ramp up. This means batteries are well suited during times of volatile demand or extreme weather to stabilize the grid. The National Grid has established contracts for enhanced frequency response (EFR) and firm frequency response (FFR), thus providing a relatively stable revenue stream for energy storage operators.

Energy management and efficiency projects
Environmentally friendly policies and changing consumer behavior have improved energy efficiency around the world. These drivers helped support the growth of renewables, energy storage and EVs. A more important implication for infrastructure investors is that power demand growth will likely remain weak in mature markets. Even with widespread EV adoption, it would be unwise for investors to assume a significant reacceleration in demand growth when evaluating investment opportunities in such markets.

Growing environmental awareness also provides some direct investment opportunities tied to the energy savings theme. We mentioned the transition towards LED lighting – penetration rates currently remain low globally and there is still further runway for LED lightbulbs to take share from incandescent light bulbs. Some investors have found niche investment opportunities to upgrade existing street lighting into LED, often as a part of larger smart city projects and in the form of a PPP. Bidding is usually conducted based on the level of lighting and the amount of energy saved.
Integrated energy management projects are also becoming a big investment opportunity, where clients (corporates, municipalities, schools etc.) are looking to improve energy efficiency in power, lighting, and heating. Ohio State University, for example, recently closed a USD1 billion deal with an energy company and an infrastructure investor for an integrated energy management project that will provide electricity, natural gas, steam, heating, cooling, and geothermal facilities to the school for 50 years. One of the project's criteria is the improvement in energy efficiency by 25% in the next 10 years. Finally, PPPs in smart city projects have gained popularity, with cities like Toronto and Atlanta looking at the private sector to provide solutions to upgrade their energy, utilities, telecom and transportation network.

Midstream and transport infrastructure for U.S. shale
The growth of U.S. shale resources has increased the need for greenfield infrastructure across the entire global supply chain to absorb the new supply. We mentioned the growth potential of LNG – although note that LNG liquefaction projects typically require multi-billion dollar investments, which could limit the participation for some infrastructure investors.

In addition, the current pricing environment is actually not conducive to new large-scale projects, as the low global gas prices have limited the appetite of buyers to sign long term contracts. This limits new investments, as developers typically want more revenue visibility before committing capital to new projects. This could gradually change, as there is general consensus within the energy industry that natural gas will become an increasingly important part of the global energy mix. We may have to wait for the correct price signals to emerge before we see a new wave of large LNG investments.

Meanwhile, some companies are exploring the development of more modularized LNG plants that require smaller upfront investments, and have more flexibility in securing long term contracts, which could interest some infrastructure investors. Finally, there are also opportunities to invest in LNG regasification plants or floating storage units at the location of the importing customers, as the capital requirements are generally lower than a LNG liquefaction plant.

For other commodities such as crude oil, distilled products, NGLs and chemicals, there are also investments opportunities in midstream gathering and processing systems, transmission pipelines, specialized export/import terminals, storage facilities, and logistics facilities across the global supply chain. For example, crude oil in the Permian basin in Texas is currently almost USD 20 per barrel cheaper than international Brent oil price – reflective of the logistical constraints and a positive sign for new infrastructure investments.

Source: Freeport LNG Development, L.P.

Taking a position

We have highlighted four key factors contributing to the global energy transition. Below we identify their impact on sub-sectors of interest to infrastructure investors. The caveat is that opportunities can vary significantly across geographies. Even within the same jurisdiction, assets in the same sub-sector can still have a wide degree of attractiveness, despite facing similar secular headwinds or tailwinds. Risk/reward profiles can also be different depending on where the investment is within the capital stack.

Our goal below is simply to highlight the risks and opportunities on a high level, and whether an investment should broadly be valued at a premium or discount.

Investments to value at a discount

Coal fired power generation

- Will continue to lose share to renewables and gas-fired power stations given inferior economics. Investors increasingly view coal-fired generation negatively from an ESG perspective, potentially impacting exit values and returns. Investments in this area must include high quality long-term contracts in regions where there is less disruption from natural gas and renewables.

Nuclear power generation

- Although nuclear power has zero carbon emissions, costs are high and political support is low. Generally speaking, there are few opportunities for private infrastructure investors aside from the waste management side.

Gas-fired power generation

- Economics vary from project to project. Growth of renewables has acted as a double-edged sword – enabling the development of some projects while eroding the economics of others (see Investments to value at a premium).

Traditional transmission and distribution

- Rising penetration of distributed renewable energy and storage poses a challenge to traditional grids, as customers purchase less power from the network. Grid assets generally earn regulated returns, shielding them from near term financial impact, although longer term, business models may need to evolve.

Midstream exposed to motor gasoline in mature markets

- The shift towards EVs will limit demand especially in developed markets, which puts midstream (and downstream) assets exposed to motor fuels in mature markets at risk. However, emerging markets demand should remain robust in the near term, which could be positive for certain import and export assets.

Investments to value at a premium

Renewables

- Secular tailwinds and a key driver behind the global energy transition. Returns have compressed, so investors seeking higher returns may need to increase their exposure to merchant, geographic, and technology risks.

Gas-fired power generation

- Benefitted from the shale revolution. Natural gas is a transition fuel, and gas-fired power stations in supportive jurisdictions with high barriers-to-entry are attractive, as they help promote growth of renewables (until battery economics catch up – see below).

Battery and energy storage

- Opportunities are currently limited for infrastructure investors, although a game-changer in the future with standalone projects or projects attached to existing renewables or grid. Disrupts inefficient peaker plants in the medium term, and baseload generation longer term.

Modern transmission and distribution

- Opportunities include T&D lines that connect renewables to load centers, smart grid for distributed resources, and EV charging stations. Technology is evolving rapidly, so investors must watch out for obsolescence risk.

Midstream exposed to U.S. shale or U.S. exports

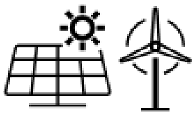
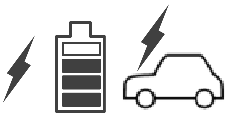
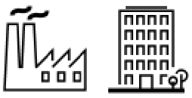
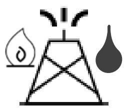
- Shale has created significant new supply of U.S. hydrocarbons (oil, refined products, gas, NGLs, chemicals etc.). Opportunities exist across the global supply chain, including gathering and processing, pipelines, storage, and export/import terminals.

Energy efficiency

- Niche investment opportunities, with integrated energy solutions to large organizations or municipalities becoming popular, although investors may need specialized knowledge to participate.

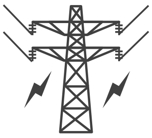
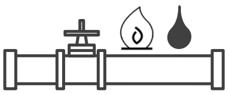
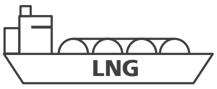
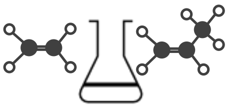
Appendix: Summary of the key disruptive forces in global energy and the impacted sectors

Figure 8: Key disruptive forces in the global energy markets

Disruptors	Relevant data	Details
Renewable Energy 	– 2017-30E global renewables (non-hydro) generation: +4% p.a. – 2030E Onshore wind cost: ~20% decline from 2018 – 2030E Solar PV cost: ~35% decline from 2018	– Improvements in technology and falling costs have made renewable energy more competitive – Increasing awareness to environmental issues has led to supportive government policies – Subsidies are being phased out, however as renewable costs continue to decline, subsidy-free renewables is simply a question of when
Batteries and Electric Vehicles 	– 2030E Battery Cost: ~50-60% decline from 2017 – 2017-30E global EV fleet: +31% p.a. – 2017-30E global battery capacity in stationary applications: +19-23% p.a.	– The success of Tesla shows that consumers have made a conscientious decision to pick electric vehicles ("EVs") over internal combustion engines – Many countries around the world are committed to phasing out ICE vehicles in the next few decades – Falling battery costs will support the growth of renewables, since it solves the intermittency problem of renewable energy
Electricity Demand 	– 2017-30E OECD power demand: +0% p.a. – 2017-30E global power demand growth driven by EVs: +0.1% p.a. – Global LED penetration only at 22% as of 2017, to rise to 63% by 2022	– Power demand growth has decoupled from economic growth in mature markets, as heavy industries shrink and energy efficiency rises – Electricity demand growth will remain lackluster despite increasing EV penetration, as vehicle demand is still starting from a very small base – There is still room for further energy efficiency gains, as LED lighting penetration still remains low and other energy saving technologies emerge
Shale Oil and Gas 	– 2017-30E U.S. oil production: +2% p.a. – 2017-30E U.S. natgas & natural gas liquids (NGLs) production: +3% p.a. – U.S. current production per Rig: +100-200% vs. 2014	– Improvements in horizontal drilling and fracking techniques revived the U.S. oil and gas industry – Natural gas is produced as a by-product (i.e. for free) in shale oil basins, which means high oil price potentially leads to lower gas prices – Low cost shale opens up export opportunities from the U.S. in the form of crude oil, LNG, refined products, and chemicals

Source: UBS Asset Management; EIA, February 2018; REN21, June 2018; IEA, May 2018; IRENA, January 2018, NREL, July 2018; BP, June 2018

Figure 9: Impact of disruptive forces on the global energy supply chain

Impacted sectors	Relevant data	Details
Conventional Power 	– 2017-30E OECD gas-fired generation: +1% p.a. – 2017-30E OECD coal and nuclear generation: -1% p.a.	– Growing renewables and cheap natural gas (especially in the U.S.) have squeezed out coal and nuclear power generation – Renewables plus batteries will disrupt all forms of conventional generation at some point, but for now, gas-fired power remains important
Transmission and Distribution 	– Cost to modernize U.S. grid: USD 17-24bn p.a. through 2030 – Western Europe smart grid investments: ~USD 13bn p.a. through 2027	– Grid capacity has lagged behind the expansion of renewables, causing congestion in areas such as Texas and Germany – New technologies such as smart grids, smart meters and EV charging stations are required to effectively incorporate distributed renewables, batteries and electric vehicles.
Oil & Gas Midstream 	– Brent crude trades almost at a USD 20 premium to Permian crude, due to infrastructure constraints along the supply chain	– Midstream capacity has been ramped up to facilitate the transport of new shale oil, gas and NGLs, including to export markets – New pipeline capacity has lagged production growth, leading to congestion and wide pricing differentials
International Trade  	– 2017-2030E U.S. LNG Exports: +17% p.a. – 2017-2030E China natural gas demand: +5% p.a. – 2030E U.S. Chemical Exports: Double vs. 2014	– U.S. is looking to monetize its shale cost advantage, and is looking to export hydrocarbons in all shapes and forms – Low cost shale gas has transformed the U.S. into a net exporter of gas using LNG, just as LNG demand from Asia is growing rapidly – U.S. is looking to export chemicals, as its NGL feedstock is lower cost than the naphtha or coal that is typically used in the rest of the world

Source: UBS Asset Management; EIA, February 2018; NREL, July 2018; BP, June 2018; Northeast Group, June 2017; IRENA, January 2018; Nexant/ACC, January 2015; Deloitte, June 2016; Bloomberg, September 2018

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