INVESTING IN POWER RELIABILITY AND FLEXIBILITY INFRASTRUCTURE
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Executive Summary

As the world’s power mix continues its structural shift to renewables, and as issues like the increasing prevalence of natural disasters and cybercrime impact networks and distribution, the emergence of new solutions to ensure power reliability and flexibility has become one of the power sector’s megatrends. In this paper, we present our thematic research into this area and outline why we believe power reliability and flexibility solutions offer compelling opportunities for transformational investing and sustainable returns globally.

- **Grid instability is an increasing concern in modern power networks:** The ability to match electric supply and demand in real time without interruption is often taken for granted. But this essential service is facing increasing challenges due to the changing mix of power production technologies and a legacy grid infrastructure that is not equipped for these challenges.

- **Several developments are destabilizing the grid – in particular the rapid growth in renewables:** The rise of intermittent renewable power is a major challenge for power grids globally. The issue is compounded by the retirement of baseload conventional power capacity (such as coal and nuclear), distributed generation, under-investment in grids, natural disasters, and cybercrime.

- **The lack of reliability is a practical and socio-economic problem:** Power outages have direct and wide-reaching impacts on society, including food spoilage, business and manufacturing shutdowns and even loss of life. Millions of people are affected by power outages every year, and annual economic losses related to these events are estimated to exceed USD 100 billion in the U.S. alone, according to the U.S. Department of Energy.

- **New flexibility solutions are emerging across the power system value chain:** As traditional suppliers of reliable energy – the conventional power plants – are being retired, we expect a more diverse set of solutions across Generation, Storage, Grid and the Demand side to provide grid stability in the future.

- **These new solutions will provide significant private infrastructure investment opportunities:** Estimates suggest that overall power sector needs amount to USD 700 billion of capital expenditure annually between now and 2050. Of this, 62% will be needed for generation and the remaining 38% for grid networks\(^1\). Flexibility solutions represent a significant share of this requirement, including USD 88 billion a year for grid networks related to renewables, USD 30 billion for gas peaker plants and USD 27 billion for batteries.

- **For investors aiming to take advantage of this megatrend, there are several key considerations:** Strong infrastructure characteristics of a potential target are crucial, including the availability of appropriate remuneration frameworks to ensure long-term stable cash flows. Due to the significant need for new build generation and grid upgrades, a substantial portion of the opportunity will be for investors who can reliably build core assets and expand infrastructure platforms.

- **At Partners Group, we focus on six key flexibility and reliability solutions where we see the most compelling risk/reward:** In Generation solutions, we focus on flexible gas power/peaking power plants and hybrid power plants; in Storage solutions, we focus on batteries; in Grid solutions, we focus on distributed/micro grid solutions and interconnectors; and in Demand solutions, we focus on smart meters and related services.

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1. Why is reliable power supply at risk?

As part of our thematic approach to infrastructure investment, we have researched the global power industry and identified six megatrends that are fundamentally altering the production, transmission, storage, and consumption of electricity (see Figure 1).

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<tbody>
<tr>
<td>Generation</td>
<td>More flexible power plants &amp; back-up supply</td>
<td>More renewables and greening or retirement of polluting plants</td>
<td>More efficient generation plants</td>
<td>Smaller power plants and prosumers (e.g. rooftop solar)</td>
<td>Remote monitoring &amp; control, forecasting, predictive maintenance</td>
<td>Vehicle-to-Grid and EV battery for utility-scale use</td>
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<tr>
<td>Storage</td>
<td>More power storage to balance intermittent generation &amp; demand</td>
<td>Storing excess green power</td>
<td>Smaller storage solutions at demand site (small batteries)</td>
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<tr>
<td>Grid</td>
<td>Denser &amp; stronger grid networks</td>
<td>Connecting green power sources to consumers</td>
<td>More energy efficient Transmission &amp; Distribution</td>
<td>Mini-grids, managing prosumer production &amp; demand profile</td>
<td>Remote monitoring &amp; control, predictive maintenance</td>
<td>Connecting EV charging stations and charging points at consumer home</td>
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<tr>
<td>Demand</td>
<td>More flexible demand responding to price signals</td>
<td>Higher demand for green power, greening of power use</td>
<td>Energy demand reduction</td>
<td>More flexible demand</td>
<td>Remote monitoring &amp; control, forecasting of demand</td>
<td>Electrification of transportation (cars, trucks, trains, ships &amp; planes)</td>
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Source: Partners Group. For illustrative purposes only

The rising complexity of global power systems

A flexible and reliable supply of power is vital to economic and social wellbeing. However, supply reliability is becoming more challenging to manage and is increasingly at risk as the power system is becoming more complex (see Figure 2). This, as we outline below, is causing blackouts at an increasing rate, with severe economic and societal consequences.

The rise of intermittent renewable power

More traditional sources of baseload and dispatchable generation, such as coal, gas and nuclear, are being displaced by wind and solar generation, which is both intermittent and unpredictable. Renewable generation (excluding hydropower) is growing rapidly, with capacity forecast to increase by around 9,600 GW over the next 30 years, equivalent to a 6.5% CAGR\(^2\). At the same time, economic and environmental pressures are accelerating the retirement of coal and nuclear capacity - around 46GW a year of net capacity loss is expected over the same period, predominantly in Europe and North America. As a result, the share of intermittent wind and solar in the worldwide power mix is expected to grow significantly, from 8% in 2019 to 48% by 2050 (see Figure 3)\(^3\).

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\(^3\) Bloomberg New Energy Finance, "New Energy Outlook 2019", June 2019
The growth of decentralized generation

Grid operators have increasingly less control over generation as baseload capacity is retired and small “behind-the-meter” plants (e.g. rooftop solar) are being adopted, with penetration increasing significantly in select markets, including South Australia and California.

Increased demand seasonality and unpredictability

Electricity demand is inherently volatile, but there are well established daily and seasonal patterns that aid grid planning and dispatch. However, as buildings increasingly electrify and electric cars become more prevalent, these patterns become accentuated or less predictable. For instance, the share of electricity in energy consumption by buildings is expected to rise from 31% in 2016 to 45% in 2050⁴, while an electric car may double a typical household’s annual electricity consumption. Smart vehicle-to-grid solutions could partially help manage the incremental load on the grid network from vehicle charging need, however we do not expect to see large-scale implementation in the near to medium term.

Climate change

Global warming and extreme weather events threaten power reliability because a warmer climate makes thermal plants less dependable and impedes their cooling systems. At the same time, changes in hydrology naturally affect hydropower output and extreme weather can damage power infrastructure.

Cybercrime

The power system is one of the most frequently attacked systems worldwide for financial, espionage, or geopolitical reasons: former U.S Energy Secretary Rick Perry recently commented that cyber-intrusions in the U.S. power sector, aimed at disrupting or even destroying energy assets, happen “hundreds of thousands of times a day”⁵.

Why renewable power poses reliability challenges

As we have outlined, wind and solar power are set to become an increasingly large part of global generation capacity. While this is a positive development as the world attempts to reduce carbon emissions and mitigate climate change, the intermittency of these sources brings a new set of challenges for the power sector.

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⁵ Testimony to the House Appropriations Subcommittee on 15 March 2018 as reported in Fortune magazine
Wind, for example, is a highly volatile resource. The power it generates can vary by a factor of eight or more over time. For example, in a single month in March 2019\(^6\), wind output in Texas ranged from as low as 2GW to as high as 17GW. This volatility will become more problematic as wind power increases its contribution to the total electricity supply and fewer back-up alternatives remain in place.

By comparison, solar power is much more predictable, but its abundance around mid-day creates different set of challenges. High solar penetration provides more power than is needed at a given time, which lowers wholesale prices. In turn, this reduces other generators' revenues and accelerates their retirement despite the fact that they are needed in the evening when solar output drops, and power demand is high. The growth of “behind-the-meter” solutions outlined above, such as residential property rooftop solar panels, is another challenge associated with solar power as these are unpredictable and can lead to grid stability issues.

Meanwhile, even where they remain in place, thermal power plants can struggle to provide adequate back-up and plug the gaps left by intermittent renewables. This is because they need hours or even days to fully ramp up their electric output; by contrast, solar and wind output tends to increase rapidly and drop almost instantly. This presents grid management challenges.

The obvious answer seems to be electricity storage; however, power storage at scale is still relatively scarce because of the high costs involved (in particular Capex). For reference, the estimated levelized cost of electricity (LCOE) for lithium ion batteries remains high today at an estimated USD 118-465/MWh (vs. USD 60-240/MWh for most conventional and renewable power generation technologies).

**Power system instability can have severe social and economic consequences**

Power instability can have a direct - and sometimes severe – impact on power producers and consumers.

The most meaningful impact is from curtailment, i.e. the act of reducing or restricting energy delivery from a generator to the electrical grid. This can affect both power generators and consumers as it can lead to blackouts. In 2019 alone, millions of people across the world were affected by blackouts: 100 million in Indonesia, 48 million across Argentina, Paraguay, and Uruguay, 32 million in Venezuela, 2.5 million in California and 1.1 million in the U.K. (see box below), to name just a few\(^7\). Perhaps surprisingly, the U.S. suffers major economic losses from power outages every year: a 2018 survey\(^8\) found that one in four companies experience a power outage at least once a month and the U.S. Department of Energy estimates annual economic losses due to power outages to be USD 150 billion\(^9\).

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\(^6\) Energy Reliability Council of Texas

\(^7\) News sources

\(^8\) S&G and Frost & Sullivan, “2018 State of Commercial & Industrial Power Reliability Report”, April 2018

\(^9\) Department of Energy, “The Smart Grid: An Introduction”
2019 U.K. blackout

On 9 August 2019, the U.K. experienced its most severe blackout for more than a decade when over a million people lost power for up to 50 minutes and nearly 1,500 trains were cancelled or delayed. A lightning strike caused an offshore wind farm and a gas power plant 100 miles apart to go offline almost simultaneously, resulting in a 5% power loss and a sudden drop in grid network frequency (see Fig. 4). As wind generation accounted for a high proportion of supply at the time – around a third – the system was unable to rebalance itself in a way that would have been possible if thermal had made up more of the total supply.

The incident was undoubtedly a rare combination of events, but the blackout highlighted concerns about the U.K. power grid’s reliability, especially as it is experiencing more near miss events. Indeed, energy consultancy Blomberg New Energy Finance (BNEF) predicts that inertia levels\(^{10}\) in the U.K. will drop by 75% over the next 20 years.

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\(^{10}\) Inertia levels = physical inertia of rotating elements in a thermal power plant, replicated across the grid, helps stabilize electric flux across the grid. Low inertia levels, or lack of inertia, can lead to more frequent frequency drops and grid instability, potentially leading to blackouts if not corrected rapidly.
2. What are the flexibility solutions?

As pressure builds on an increasingly complex power system, new flexibility solutions are being designed to ensure end-users have access to electricity as and when they need it. Supply-side power generation plants, which have historically provided flexibility, look set to be displaced by new systems and technologies, many of which will require significant investment.

The four elements of the power system value chain

Flexibility has traditionally been provided by the supply-side, in the form of power generation plants responding to grid dispatch orders. However, we expect a more diverse landscape in the future that stretches across all elements of the power system value chain as follows:

- **Generation**: This segment includes traditional and emerging power generation technologies, such as natural gas peaking plants, hybrid power plants, as well as related solutions such as carbon capture and storage. Traditional power plants generally provide the most flexibility to the system because they are "dispatchable", as long as they have access to fuel and are not under maintenance.

- **Storage**: Energy storage includes mechanical storage, such as pumped-hydro storage and flywheels, electromechanical storage, such as batteries, and fuel storage, such as hydrogen. Storage solutions stabilize the electric grid by absorbing excess supply or then discharging to meet excess demand. However, a key consideration around storage is the often high initial and/or running costs.

- **Grid**: Flexibility can be increased by strengthening the electric grid network to enable a larger universe of power generation sources to meet demand from a larger pool of end-users. This increases the efficiency of the overall electric flow and is particularly important where less reliable generation sources, such as wind and solar, are dominant in the power mix and are located far from demand centres (this is often the case in Germany and China, for example).

- **Demand**: Demand is traditionally inflexible as household, commercial, and industrial consumers expect reliable electricity supply whenever they need it. Interruptible demand schemes can provide flexibility on the demand side and these can offer compensation for end-users, while smart meters can allow customers to respond to differentiated power pricing signals over time. Electric vehicle (EV) charging is a game-changing development as EVs require large amounts of power and users could be incentivized to charge at different times of the day via pricing or other mechanisms.

Through our research, we have identified 19 distinct solutions across the power system value chain that provide varying degrees of flexibility (see Figure 5).
Generation

There are three main flexibility solutions on the generation side. Flexible natural gas power plants and peaking power plants, such as open cycle gas turbines or gas engines that can ramp up and down quickly are mature solutions with around 300GW of installed capacity worldwide and they typically have a relatively low capex. Virtual power plants (VPPs), including software and communications platforms that aggregate small power plants and/or end-users into large "virtual" plants, will experience broader adoption as distributed solutions become more mainstream. Meanwhile, Hybrid power plants, for example pairing gas, wind, solar, and/or batteries on a single site to firm up power generation output, are currently attracting a lot of interest from investors globally.

Storage

The traditional energy storage solution is pumped-storage hydropower, used by hydroelectric power stations to pump water back into a reservoir to store energy. This type of storage accounts for 98% of all electricity storage capacity deployed worldwide today. Electromechanical batteries, which are mainly lithium-ion batteries with a storage capacity of one to four hours, are experiencing rapid growth, albeit from a low base. Meanwhile, hydrogen, which can be produced from hydrocarbons or excess renewable electricity and then stored/transported via existing natural gas infrastructure, holds significant potential over the longer term as both a long duration storage medium and as a low or even zero-carbon fuel for residential and industrial uses.

Grid

Connecting more electricity generation points to more demand centers introduces greater flexibility into a grid. High-voltage transmission lines and interconnectors, i.e. copper cables transmitting electricity at a high voltage to minimize losses over longer distance, are a key solution to firming up the system.

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Demand

Smart meters, i.e. metering devices that allow remote communication between utilities and consumers, and electric vehicle charging, especially smart charging functionalities, are two of the key solutions with potential to increase demand flexibility. Smart meters are approximately halfway through their global roll-out with around 1 billion devices installed worldwide at the end of 2017 (a penetration of 50%), whereas electric vehicles have only just begun to penetrate global fleets, with a 3% share of annual car sales today, although this is expected to increase to over half in the 2040s.\(^\text{12}\)

What drives the adoption of flexibility solutions?

While there are a variety of solutions in the market, not all of them will be widely adopted. There are several factors at work that will determine their adoption rates and, ultimately, viability as investment options.

One of the most important considerations is the existing power system architecture in different markets. Each market has specific needs; from short duration storage in solar PV-dominant systems, to long duration storage and peaking generation in wind-heavy systems. Energy and environmental policies also have an impact on power system architectures and flexibility choices. Countries that have announced or legally adopted net carbon-neutrality targets, for example, are receiving more investor interest in nascent flexibility solutions, such as hydrogen or carbon capture, and these potentially compete against gas peaking plants and batteries. Germany’s recent announcement to subsidize the construction of 5 GW of renewable hydrogen capacity by 2030 can be contrasted with the U.S. policy framework that still favours natural gas (with the gradual adoption of carbon capture). However, individual states are adopting more stringent policies in this regard, for example California, which recently ordered the phase out of the internal combustion engine and banned the sale of all new gasoline-fuelled cars after 2035.

New technology is another significant factor. Advancements in software development are heralding new flexibility solutions, including VPPS and smart grids. As technology progresses further, these solutions become more attractive and the power system shifts to a "smart" network.

Finally, cost competitiveness clearly plays a major role in adoption. While large dispatchable generation plants have historically offered low LCOE of USD 65-240/MWh, the more expensive large-scale batteries (with LCOE of USD 118-465/MWh)\(^\text{13}\) are expected to see a rapid decline in cost over the coming years. As this happens, these, and solutions such as renewable hydrogen, will become far more competitive options (see Figure 6).

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\(^{13}\) Bloomberg New Energy Finance, "New Energy Outlook 2019", June 2019
What makes an attractive regional market?

While power system reliability is becoming an issue globally, not all markets are equally attractive for investors. When assessing whether a power reliability and flexibility investment is appropriate in a certain region, the current architecture of a power system is a key consideration. Typically, where renewable generation is high or the system more decentralized, the need for power reliability and flexibility solutions will be greater. In our research, we have identified six main power system architectures with distinct needs (see Figure 7).

BNEF’s forecast for the penetration levels of various electricity supply sources over the next 30 years to 2050 provides useful indications for the likely trajectory of various power markets globally. The next decade will be weighted towards wind power, as the share of onshore and offshore wind in worldwide electricity supply is set to more than double from 6% to 15%. Penetration levels in Europe will be even higher, with an expected increase from 14% to 43% of total generation, while in the U.K. and Germany wind power generation penetration is expected to exceed 60% and 50%, respectively.

Beyond 2030, solar is expected to dominate renewable generation growth globally. Solar penetration is set to accelerate significantly in the post-2030 era, with its share rising from 9% in 2030 to 22% by 2050, displacing coal. Some countries, including Australia, Chile, Mexico, and Thailand, are set to reach levels of over 40-50% of solar generation.

<table>
<thead>
<tr>
<th>System Architecture</th>
<th>Characteristics</th>
<th>Preferred Solutions</th>
<th>Country Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseload Fossil Fuel &amp; Nuclear</td>
<td>• Large centralized power plants (coal, gas, nuclear) and high capacity transmission to demand centers, relatively static demand</td>
<td>Large Thermal Plants</td>
<td>China, France</td>
</tr>
<tr>
<td>Natural Gas Dominant</td>
<td>• Power system weighted towards gas generation (centralized or distributed), often due to abundance of local resources</td>
<td>Gas Power Plants</td>
<td>Thailand, United States</td>
</tr>
<tr>
<td>High Hydropower</td>
<td>• Power system where hydropower represents a large share of total generation and is thus subject to weather / rainfall patterns</td>
<td>Large Capacity &amp; Duration / Seasonal Backup</td>
<td>Norway, Colombia</td>
</tr>
<tr>
<td>High Solar</td>
<td>• High share of solar power challenges power reliability, more flexibility required</td>
<td>Fast-Response / Short Duration</td>
<td>Australia, Chile</td>
</tr>
<tr>
<td>High Wind</td>
<td>• High share of wind power (often distant from demand) challenges power reliability, more flexibility required</td>
<td>Fast-Response / Wide Range of Duration</td>
<td>UK, Germany</td>
</tr>
<tr>
<td>Distributed Flexible Demand</td>
<td>• High share of decentralized gas based plants (e.g. CHP) and renewables (e.g. rooftop PV), network of self-reliant microgrids</td>
<td>Mix of Solutions</td>
<td>None at country level</td>
</tr>
</tbody>
</table>

Source: Partners Group. For illustrative purposes only.
Note: Each country will be at a different stage of development and may follow a different path to a low carbon emission system.
Over the next decade, the most attractive regions for power reliability and flexibility investments are likely those with a high share of wind power. Most of these regions are in Europe and include the U.K., Germany, and Southern Europe. After 2030, most of the growth in new generation capacity is expected to be in solar, which unlocks a larger market opportunity across multiple geographies incl. Australia, Southeast Asia, select European countries and the U.S.

Which solutions will matter in the future?

The next two decades will see significant shifts in the way power systems build-in the flexibility needed to service economies and populations. Based on our experience and research, we expect to see the following developments.

Traditional generation side-solutions will decline in attractiveness

Although gas generation has a key role to play in the near term as a bridge to accommodate more renewables, we expect generation-side flexibility solutions such as gas peaking plants to gradually lose their pre- eminent role because they are not flexible enough to accommodate rapidly changing renewable output. They are also typically fossil fuel-based and therefore increasingly subject to environmental regulation. Emerging markets, such as India and China, will be exceptions to this, as will countries with less stringent environmental policies, such as the U.S., where natural gas-based power generation will serve as a bridge to a long-term, low-carbon energy future.

Storage will increase in importance

We expect storage solutions to become the most predominant flexibility solution in the coming decades as they partially replace generation-side flexibility. Lithium-ion battery storage is likely to scale up rapidly once costs decline further, however, a combination of both short-duration storage (e.g. batteries) and long-duration (e.g. pumped-hydro) will be needed. And while hydropower is critical for seasonal flexibility, it faces development constraints in most developed markets due to the lack of available sites and increasing environmental costs of developing these large-scale projects. Therefore, we expect most growth in this solution in emerging markets.

Users will be less willing to pay for the power grid

Connecting new renewable energy sources and new demand centers, plus upgrading networks to smart and connected solutions, will require annual investment of USD 266 billion. And while strengthening the grid is critical to resilience and managing renewable intermittency, the increasing penetration of “behind-the-meter” generation will shrink the customer base that pays for the grid network. This will cause a potential funding gap. As a result, we expect the sector to be increasingly open to private capital to finance the shortfall, with opportunities for greenfield investment in high voltage lines, interconnectors, and smart meters.

Electric vehicles will disrupt the demand side

The demand side will continue to play a relatively minor role in providing flexibility until electric vehicles become commonplace. Indeed, EVs will be a major demand side-disruptor because their adoption will shift large amounts of power demand throughout the day. However, they are some way from being a tangible flexibility investment opportunity because of current low penetration levels and a lack of widespread vehicle-to-grid infrastructure.

How big is the opportunity?

The need for more flexibility in the power system will require substantial investment across the power sector value chain globally. Across the overall power sector, BNEF expects future capex of USD 21.7 trillion from 2019 to 2050, or an average USD 700 billion a year. Of this, new power generation is expected to account for 62%, while transmission & distribution (T&D) will represent 38%.

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On the power generation side, Asia-Pacific will require the most investment with USD 187 billion a year, or 43% of the world total, to meet fast-rising electricity demand. Capex spend is expected to reach USD 84 billion, or 19% in Europe and USD 61 billion, or 14% in the Americas) flowing predominantly towards new renewable power generation capacity and flexible solutions. On the other hand, Europe will receive the most investment in T&D assets (USD 92 billion, or 35%) to replace aging infrastructure and connect new renewable power resources to demand centers (see Fig. 8).

Storage and grid solutions are expected to rise in importance and provide more of the flexibility services traditionally provided by thermal generation plants. Gas generation has a key role to play in the near term as a bridge to accommodate more renewables although its role will gradually fade out as batteries, electric vehicles, and hydrogen become more mainstream. Hybrid power plants that combine gas generation with battery storage can offer attractive solutions and provide additional flexibility. Most of the opportunity set is expected to be in new-build opportunities. These are more suitable for investors with experience in managing assets through construction and successfully delivering projects through to their operational phase.
3. What are the investment considerations?

What we look for

While we examine a broad set of due diligence considerations, there are some specific factors that we focus on when evaluating investments in power reliability and flexibility. These can affect the risk/return profile of the underlying opportunities and the overall investment feasibility within a diversified private infrastructure portfolio.

Strong infrastructure characteristics

As with all our infrastructure investments, we favor essential infrastructure assets and businesses with a strong physical or intangible asset base in core OECD geographies where we benefit from pre-existing deep expertise and relationships. We also focus on assets that offer significant value creation potential through our three strategies - Operational Value Creation, Platform Expansion, and Building Core. As mentioned earlier, the power reliability and flexibility sector offers substantial opportunity for investors who can reliably build core assets and expand infrastructure platforms, due to the significant need for new build generation and grid upgrades.

Stable, long-term cash flows

We prefer assets that generate most of their revenues from long-term contracts with predictable cost trends. However, several flexibility solutions generate revenues predominantly linked to merchant power prices. As a result, we focus on assets that offer the right balance between merchant and contracted cash flows. Contracted revenue streams, such as capacity market payments and ancillary services, are sometimes available but they are typically provided on a short to medium-term basis and/or through competitive auctions. Revenue "stacking" can be a solution, where a flexibility asset secures multiple revenue streams providing diversification and potential upside.

Greenlink Interconnector

In 2019, Partners Group committed equity to build the 500MW Greenlink Interconnector, a sub-sea, regulated power interconnector that runs for 200km between Ireland and the U.K. The project benefits from European Union 'Project of Common Interest' status that incentivizes interconnection, improves the security of supply and the efficient integration of renewable generation. Greenlink will contribute 33% to Ireland’s existing connection capacity and 11% to that in the U.K. Greenlink stacks revenues from congestion rents that are generated by pricing differentials between the Irish and U.K. markets, capacity market payments and ancillary services on top of a regulated cash flow base.

Strong market position with high barriers to entry

In the flexibility sector the level of operational and commercial flexibility of the assets is key to their market strength and positioning: more flexible assets tend to be more valuable and display a lower risk of obsolescence. There are ways of increasing flexibility, including improving technical parameters, for example, as more flexible gas-fired power plants have an advantage over less flexible ones, and redeploying an asset to capture new market opportunities, for example by relocating a battery storage project to a different part of the grid that is facing higher congestion.

Sentinel Energy Center

Sentinel Energy Center is an 800MW operating, simple-cycle natural gas-fired power generation facility that holds a strong competitive position as a key asset in the Los Angeles Basin load center. Sentinel is the largest plant of its type in the world, with eight GE LMS100 quick-start turbines that can come online within 10 minutes. Its location in the LA Basin makes Sentinel ideally positioned to respond to a significant and growing demand for fast-ramping generation that is driven by growth in the Californian renewables sector and...
tightening reserve margins caused by regulation-driven plant retirements. Sentinel entered commercial operations in May 2013 and generates all revenues under a 10-year availability-based power purchase tolling agreement with the local regulated electricity utility. We expect that Sentinel will be re-contracted before the end of its existing agreement because of its position as a strategic, low-cost, and highly flexible asset within a market that will have an increasing need for flexible capacity and that has high barriers to entry for new build thermal power projects.

Platforms versus single assets

We have a strong preference for platform investments with a combination of assets that are operating, under construction and in the pipeline. Platform investments have several advantages over single asset investments, including the potential to deploy significant amounts of capital at scale, create value by de-risking projects from development to construction completion, and capitalize on cost efficiencies across projects. In addition, they offer the opportunity for efficient capital allocation between different projects in terms of size, geography and complexity, and risk diversification across projects in terms of geographies, markets, revenue streams, counterparties, and sectors and technologies.

EnfraGen

EnfraGen is a leading developer, owner and operator of power generation assets in OECD/investment grade countries in Latin America, Colombia, Chile, and Panama. The EnfraGen platform provides back-up power for grid stability and baseload renewable power generation. It consists of 17 assets and has multiple revenue stream structures, including PPA, regulated capacity and merchant dispatch revenues. The portfolio is also diversified across a mix of technologies, including reciprocating engines installed to provide backup power generators, a combined cycle gas turbine plant, as well as hydro and solar. EnfraGen is a scalable operating platform with visible growth opportunities, and Partners Group aims to expand the platform via strategic acquisitions, infill projects that leverage the existing sites' permits, and interconnection and other asset optimization and organic growth initiatives.

Low disruption risk

Flexibility solutions are expected to benefit significantly from power grids' structural transformation. However, with change comes technology and market risk. Each solution will face different competitive pressures in different power markets across the world. Navigating the complex power sector requires deep sector expertise and local market knowledge to reduce tail-end risk.

Near-term transactability

Finally, we prioritize investments where we see a credible path to execution. This includes investments in proven technologies with a track-record of commercial adoption, and situations where we can establish a competitive advantage through either prior investment in the sector, existing operational expertise, or a wide, sector-specific relationship network. In addition, we seek investments that have the potential to offer returns within our target range and that are achievable under a conservative base case, with additional optionality built on top via value creation initiatives.
Partners Group investment focus

After applying all these criteria to the solutions we outlined earlier, we believe that the following power reliability and flexibility solutions offer the most compelling investment opportunities across the value chain.

Generation

- **Flexible Gas Plants and Peaking Power Plants:**
  - **Technology:** Open-cycle gas turbines or gas engines that can ramp up/down more quickly than combined cycle gas turbines or coal power plants
  - **Market:** 300GW installed worldwide, growth of 5% CAGR expected to 2050
  - **Value proposition:** Faster response (and lower capex) than traditional power plants to meet peak electricity demand and/or offset renewable fluctuations
  - **Transactability:** Sizeable construction projects & operating assets available as well as platforms
  - **Key risks:** Merchant risk; competition from batteries (medium term); ESG (long term)

- **Hybrid Power Plants (project co-siting):**
  - **Technology:** Pairing gas, wind, solar, and/or batteries on a single site to firm up power generation output and maximize grid connection capacity usage
  - **Market:** Pilot stage
  - **Value proposition:** Wind/solar/battery combinations firm up output to the grid, gas/battery combinations increase operational flexibility of the project
  - **Transactability:** Mix of greenfield projects and opportunities for "retrofits" as a value creation strategy
  - **Key risks:** Renewable resource availability; merchant exposure

Storage

- **Batteries:**
  - **Technology:** Various electrochemical configurations, but lithium-ion dominates, short duration storage capacity (typically < 4 hours)
  - **Market:** Emerging, with 2 GW installed worldwide and growing at 55% CAGR over the past 5 years
  - **Value proposition:** Highly scalable, low development and construction risk, good match for bridging the gap between peak solar generation mid-day and peak electricity demand in early evenings, fast response and high cycling capability
  - **Transactability:** Few existing platforms > 100MW but significant greenfield potential
  - **Key risks:** Merchant exposure, cannibalization risk as more batteries are added to system (lower barriers to entry), performance degradation over lifetime, declining replacement value

Grid

- **High voltage & Interconnectors**
  - **Technology:** Copper-based electric cables that transmit electricity at high voltages over long distance (up to 5,000 miles). These cables can be installed overhead, buried underground, or laid over the seabed. Interconnectors connect grid networks in different countries

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• **Market:** Very large market with significant growth ahead with an expected 2 million kilometers of new high voltage lines added over 2019-2050

• **Value proposition:** Unlocks remote renewable resources and strengthens grid resilience

• **Transactability:** Most large-scale targets typically state-owned and/or regulated with low returns, but opportunities for private ownership in developing markets and greenfield development in Europe

• **Key risks:** Construction risk; regulatory regime/remuneration changes

### Demand Management

• **Smart Meters**

  • **Technology:** Electricity consumption metering devices with the ability to communicate remotely with the utility (1st generation) or two-way communication to send price signals and control smart appliances (2nd generation)

  • **Market:** 1 billion smart meters installed worldwide by the end of 2017 (50% penetration); expected to double by 2030.\(^\text{17}\)

  • **Value proposition:** Limited contribution from 1st generation meters but 2nd generation meters can help shift discretionary demand to off-peak hours, helping absorb renewables and limiting the additional grid investment needed to meet incremental peak demand

  • **Transactability:** Sizable existing platforms and further greenfield opportunities

  • **Key risks:** Customer churn; most greenfield weighted towards emerging markets; labor-intensive sector exposed to labor cost inflation

### Integrated Solutions

• **Distributed/microgrid-solutions**

  • **Technology:** "Off grid" generation including renewables, e.g. rooftop solar, or gas, e.g. combined heat & power (CHP) and distribution of electricity

  • **Market:** Relatively small today but significant growth expected in the future

  • **Value proposition:** Off-grid applications shield customers from unstable grid supply and blackout risks

  • **Transactability:** Several large-scale distributed solar companies, otherwise mostly greenfield opportunities

  • **Key risks:** Customer acquisition / scalability costs and merchant exposure

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About Partners Group

Partners Group is a leading global private markets investment manager. Since 1996, the firm has invested over USD 145 billion in private equity, private real estate, private debt and private infrastructure on behalf of its clients globally. Partners Group is a committed, responsible investor and aims to create broad stakeholder impact through its active ownership and development of growing businesses, attractive real estate and essential infrastructure. With over USD 109 billion in assets under management as of 31 December 2020, Partners Group serves a broad range of institutional investors, sovereign wealth funds, family offices and private individuals globally. The firm employs more than 1,500 diverse professionals across 20 offices worldwide and has regional headquarters in Baar-Zug, Switzerland; Denver, USA; and Singapore. It has been listed on the SIX Swiss Exchange since 2006 (symbol: PGHN). For more information, please visit www.partnersgroup.com or follow us on LinkedIn or Twitter.

Infrastructure at Partners Group

Partners Group’s private infrastructure business has an established track record of investing in essential infrastructure with value creation potential on behalf of its clients since 2001. Partners Group’s strategy takes a global relative value approach focusing on assets with true infrastructure characteristics in high conviction themes, and aims to bring greenfield projects to the operational stage, building individual assets into platforms thereby generating attractive returns to the benefit of all stakeholders. Partners Group’s specialized infrastructure research team works with 80 dedicated infrastructure investment professionals to identify long-term structural trends and disruptions in the investment landscape. Since inception, the firm’s private infrastructure business has invested over USD 11 billion across more than 140 investments, and today has USD 16 billion in assets under management.

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