RISING
TO THE CHALLENGE

Building the bridge to the future:
Investing in today’s energy infrastructure, to be the catalyst of a low-carbon Europe tomorrow

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EXECUTIVE SUMMARY

The energy ecosystem has experienced significant change in recent times. The combined forces of decarbonisation and digitisation are bringing about major implications on the existing European fleet of fossil-fuelled power plants. Whilst these plants will remain an important part of the energy system for many years to come, load factors are being squeezed and in turn, profits are being reduced.

Renewable energy is no longer a passing trend. Decarbonisation of the power sector requires deploying significant volumes of renewable power generation. The European Commission has set ambitious climate commitments by proposing a binding level of 27% share of renewable energy consumed in the EU by 2030. The system integration costs of variable renewables will be very high unless the system becomes more flexible. Whilst new sources of flexibility are emerging, the change is not quick enough to prevent the risk of escalated costs. It is also imperative to realise, whilst the 30+ countries across the European continent fully support the Paris agreement, they all have different starting points, economic advancements, policies and installed energy systems.

Today, the existing infrastructure is the backbone of the European energy market. To power the continent, we must enhance this energy infrastructure to meet tomorrow's challenges. Rather than being a casualty of the changes, GE believes the existing fleet is an important facilitator of system change, one that will be a bridge to the future, and its contributions should be recognised to support this transformation. In particular, investments in efficiency, flexibility and cleaner power generation will provide the best insurance to secure profitable on-going operations and eventually keep the transformation on track and the costs low.

Fortunately, these technologies exist to help existing power generation assets rise to the challenge by becoming more flexible and efficient, thereby ensuring that the deployment of renewables can continue without concern. GE is now able to provide upgrade solutions and digital plant performance optimisations that integrate all necessary equipment technologies through its Fleet360* total plant solutions approach, delivering significant improvements for steam and gas plants.

The European power system is embarking on an exciting journey of change. It is important that all actors commit to this journey by taking the early steps that are available and can be implemented now. This White Paper sets out the importance of thermal power plants and the opportunities that exist to create a win-win situation for power generators and policy makers driving the energy system transformation of the European continent.

AN ENERGY ECOSYSTEM IN TRANSITION

The energy ecosystem worldwide is experiencing major change.

These changes are being driven by two factors. First, the threat of climate change is now widely appreciated and the international community has agreed to limit the rise in global temperatures to less than 2°C at the landmark Paris conference in 2015. Low carbon power generation technologies, primarily renewables, are readily available and deployable, and the decarbonisation of power systems represents the easiest way to achieve early reductions in carbon emissions[1]. Also, the European Union is taking a leadership role to tackle climate change[2] and, therefore, the European power system is at the forefront in feeling the effects of measures to decarbonise the power system.

The second factor is the emergence of new digital technologies. The ability to easily capture access and process huge amounts of data, as well as automatically control appliances has the potential to radically alter the way electricity is produced, distributed and consumed. Whilst the impact of these changes is likely to be most significant in improving the efficiency and flexibility of energy consumption, there are immediate opportunities for electricity producers to take advantage of these technologies to improve business performance.

These changes to the European power system will have stark consequences for the existing fleet of European fossil-fuelled power plants. While the extent of the impact depends on the age of assets, the speed at which low carbon replacements are built and the degree to which consumer behaviour is evolving, the impacts are already visible. Load factors are being squeezed and output is increasingly being reduced – many plants are finding it challenging to justify continued operations. The future for gas-fired plants is likely more robust than that for coal-fired plants, given that emissions are lower and that they provide flexibility and back-up capacity as more renewable capacity comes online.

It is tempting to think of fossil-fuelled plants as a casualty of the energy system transformation, resulting in minimised investment as it embarks on a glide path towards closure. However, GE thinks differently. It is almost impossible to simply switch off existing power generation assets and turn on renewable power generation, from one day to another without risking affordable and reliable energy. This is a journey, and the existing installed base will play a very important role in this transformation. Today, most electricity is produced by a thermal fleet that is 30 to 40 years old – and this will continue to be needed for many years to come. Currently, this infrastructure is the backbone of the European energy market and to power the continent, we must enhance this existing energy infrastructure to meet tomorrow's challenges and minimise the system integration costs of renewable generation. We believe the existing fleet is an important facilitator of system change that should be invested in to support the transformation.

Even if policy makers decide to pursue decarbonisation more aggressively than currently foreseen, investing to modernise fossil power plants provides the best insurance to secure profitable on-going operation.

[1] The largest source of man-made atmospheric CO2 are electricity and heat generation (42% globally)" see: https://www.gepower.com/content/dam/gepower-pw/global/en_US/documents/energy-ecosystem/decarbonization.pdf

[2] http://europa.eu/rapid/press-release_IP-15-5358_en.htm

THE ROLE THERMAL PLANTS CAN PLAY

Figure 1: A smart and sustainable energy system.

There is increasing consensus about the energy system of the future. As the proposals to create an Energy Union were launched, European Commission Vice President Šefčovič set out his intent to create an "Energy Union" with citizens at its core - where they take ownership of the energy transition, benefit from new technologies to reduce their bills, and participate actively in the market[4]. The access to affordable, reliable energy is critical to sustaining and growing economies and is fundamental to quality of life in the modern world.

Energy powers our factories, provides light to study, enables access to clean water, heats our homes, transports products and people, refrigerates foods and medicines, and connects us to information in a digital world. Each year, $5 trillion is spent across the entire energy ecosystem globally, from capturing natural resources through their final consumption by end users. Multiple technologies, fuels and industries work in concert across the energy ecosystem to provide energy in the form and quantity required, with desired reliability, at the lowest possible cost. This energy ecosystem is undergoing unprecedented changes driven by advancements in technology, growing concern for the environment, changing consumer behavior, new policies, changes in fuel availability and pricing, and resource constraints. Changes within one segment of the ecosystem can have dramatic effects on the whole cycle; subsequently the increase in renewable generation has a significant effect on other power generation assets.

However, despite the consensus over the ultimate destination, there is little agreement over how, and when the transformation will occur. What is clear is that the extent of the change is such that it will not happen quickly, and we cannot abandon our existing energy system and associated assets in the near future.

It is also vital that the transformation is not viewed as entirely negative for the existing asset portfolio or something that should be fought and obstructed. Instead, these assets have a big role to play in creating a bridge to the future and their contribution should be recognised and rewarded.

Interestingly, the policy intention has previously focused on the efficiency of energy consumption and less on the technical processes involved in the production, conversion and transportation of energy. And yet the potential benefits from these processes are enormous.

Today, 41 percent of global electricity generation comes from coal-fired power plants and 22 percent comes from gas-fired power plants. In December, 2016 GE released a first-of-its-kind analysis of global power plants.

The study found that CO2 emissions from the world's fleet of coal and gas power plants can be reduced by 9% - the equivalent of removing 168 million cars off U.S. roads - when existing hardware and software solutions are fully applied. GE's study also found that existing coal plants can be made 3.4% more efficient with more than half of the improvement coming from turbine and boiler updates, and an average 1% by applying the latest digital solutions.

Upgrades to existing plants can be done relatively quickly and cost effectively. They aren't reliant on new technology introductions to come or lengthy processes for permitting, funding and/or building new plants. In Europe, the vast majority of the active plants are more than 25 years old. If GE technology is applied on all of them, the results could be significant. These benefits are available now and promise the most effectiveness if accepted early – the sooner efficiency is improved, the greater the benefits in terms of avoided emissions and costs saved.

Improving efficiency, however, is only part of the story. Decarbonising the power sector will inevitably involve dramatic increases in the amount of electricity produced from renewable energy sources; the European Commission's proposal for a revised Renewable Energy Directive to make the EU a global leader in renewable energy and to ensure that the target of at least 27% renewables in the final energy consumption in the EU by 2030 is met. Most renewable power production involves technologies that are 'variable' in output and generate power in line with changing natural energy resources (wind and solar) rather than changing consumer demands.

Similarly, nuclear power plants are inflexible, and it is difficult to change the reactor load as demand varies. This, in turn, increases the challenge of balancing supply and demand and creates the need for more flexible system resources.

Although new sources of flexibility are emerging (interconnector trading, storage and demand side response), these will take time to establish and cost-effectively provide the level of flexibility required. Therefore, this residual load will need to be met largely by existing thermal power generation for a significant time to come.

The costs of inflexibility can be very high since it considerably increases the cost of integrating renewables onto the system. Unfortunately though, these costs are likely to begin to increase in the almost immediate near future.[3]

Therefore, improving both efficiency and flexibility of existing thermal power plants represent an important step towards creating the energy system of the future.[4]

[3] Recent analysis by E3G and Imperial College has studied system integration costs of renewables in Great Britain and concluded that early action is needed to increase the flexibility of the energy system. See: https://www.e3g.org/library/plugging-the-energy-gap

[4] Energy Union Communication: http://ec.europa.eu/priorities/energy-union/docs/energyunion_en.pdf

OPPORTUNITIES TO IMPROVE BUSINESS PERFORMANCE

FLEXIBILITY

Technological innovations continue to present new opportunities for power plant owners to improve the performance of their plants and adapt to changing market requirements. Applying new digital techniques to gather and process operational data shines light on where the biggest improvements can be made. Indeed, GE is now able to create solutions to optimise plant performance that integrate all the necessary equipment technologies across the power plant through its Fleet360* total plant solutions approach[5]. For example, Figures 2 and 3 illustrates how this approach can significantly improve steam and gas plant flexibility.

GE is already applying its Fleet360* approach at both gas and coal-fired plants around the world. For example, Uniper UK Ltd. selected GE to provide plant equipment upgrades and advanced digital solutions to boost the performance of its Enfield and Grain combined-cycle power plants in the high-demand areas of greater London and southeast England[6]. Also, GE will modernise Hrvatska Elektroprivreda d.d.'s site in Plomin, Croatia, the only coal-fired power plant in the country. These retrofits will help improve the plant's heat rate, increase its power output, lower its operational and maintenance costs, and extend the operating life of the steam turbine[7]. Perhaps most exciting is the fact that solutions

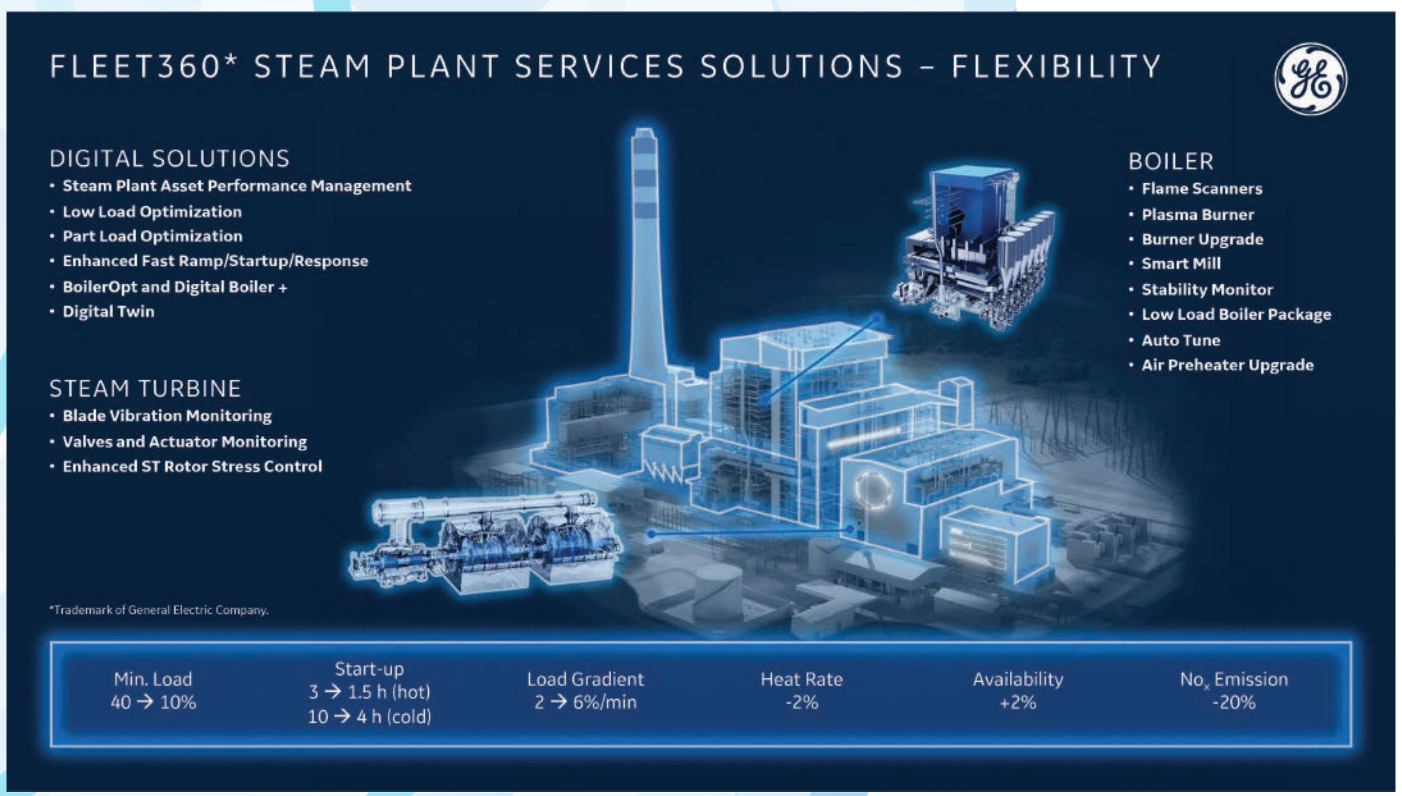


Figure 2: Improvements available in steam plant flexibility

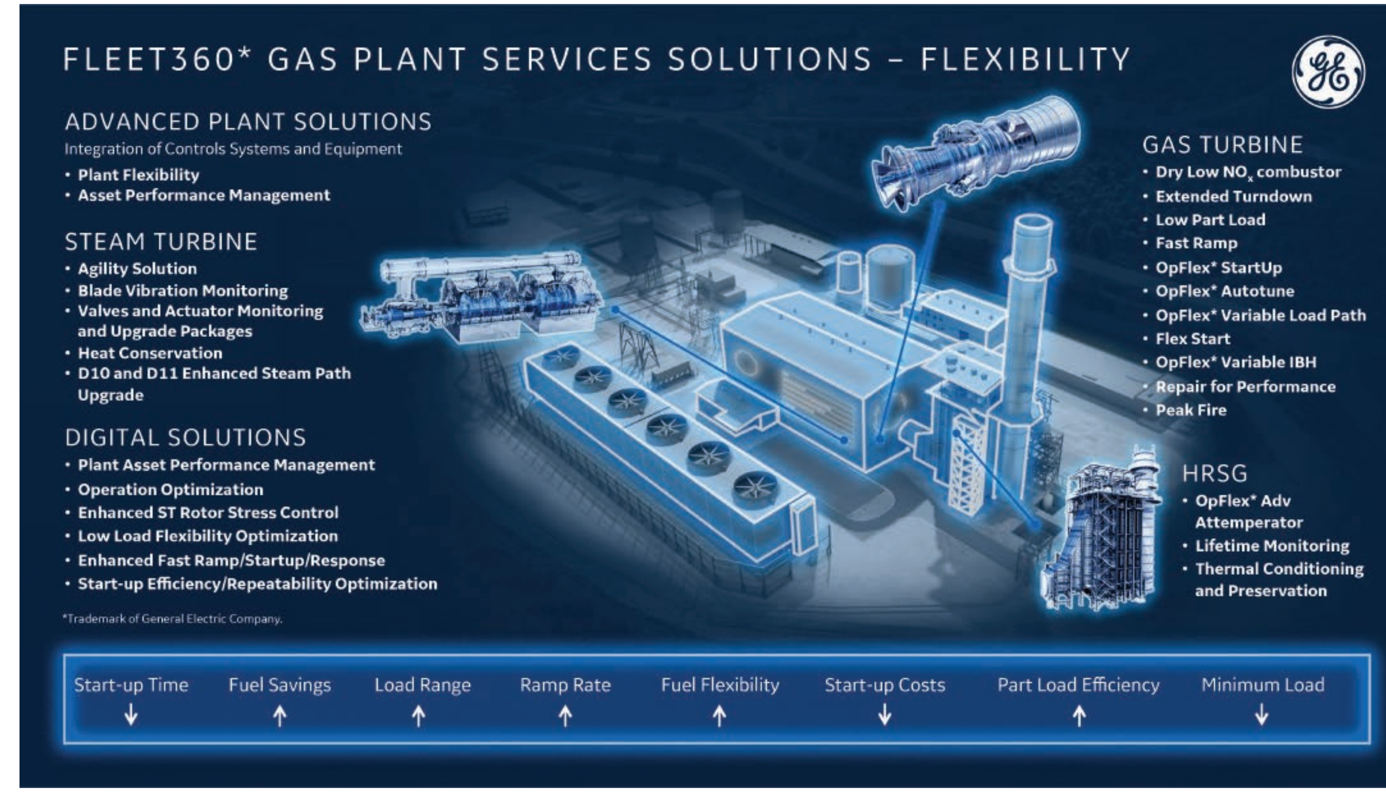


Figure 3: Improvements available in gas plant flexibility

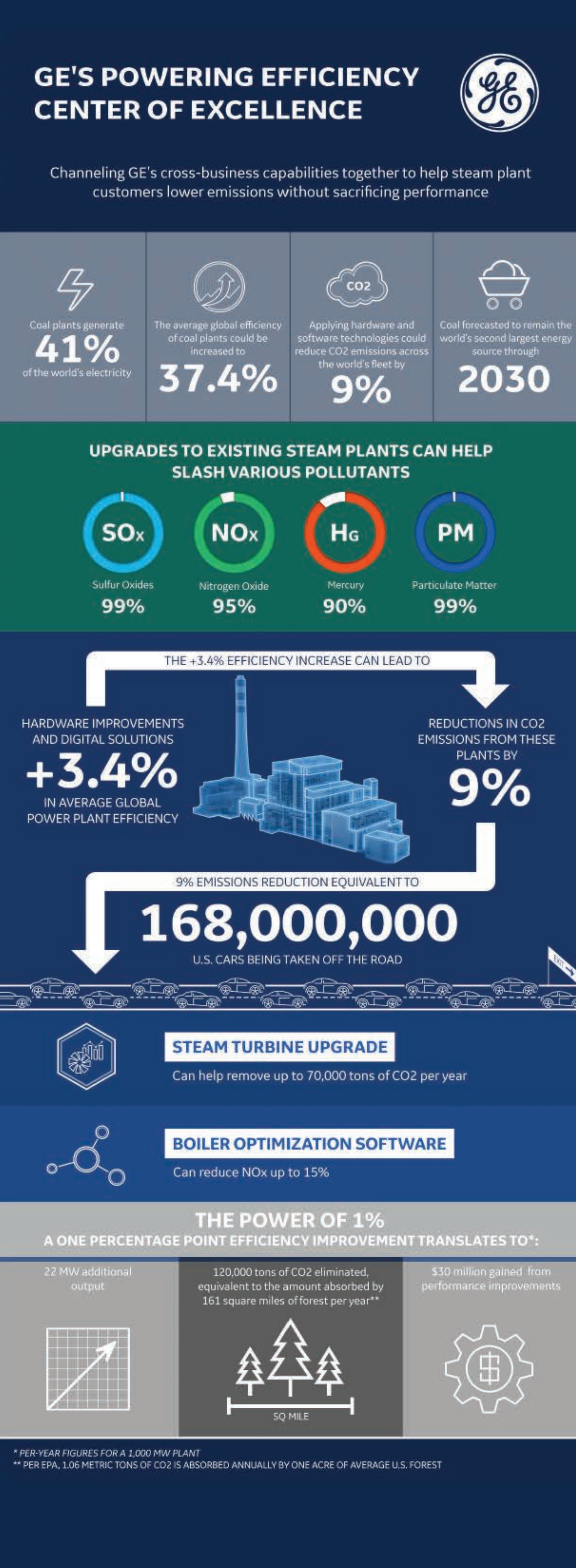
can breathe new life into assets that had been unable to compete in the marketplace. A2A's Chivasso site in Italy was mothballed three years ago because the power plant could not respond quickly enough to changing grid demands. However, Chivasso was re-opened in November 2015 following several hardware and software upgrades from GE. A2A took its first step towards a digital industrial transformation by achieving a 65 megawatt (MW) per gas turbine minimum load level — the best in GE's 9FA fleet—and enabling load ramping at up to 50 MW per minute, or two-and-a-half times the normal rate[8].

[5] *https://powergen.gepower.com/services/fleet360-total-power-plant-solutions.html*

[6] *http://www.genewsroom.com/press-releases/uniper-chooses-ge%E2%80%99s-fleet360-total-plant-solutions-%E2%80%98future-proof%E2%80%99-two-uk-power-plants*

[7] *http://www.genewsroom.com/press-releases/ge-help-increase-output-and-performance-croatian-coal-fired-power-plant-283425*

[8] *https://www.ge.com/digital/stories/our-fleet-including-our-other-two-combined-cycle-power-plants-cassano-and-sermide-will-reap*



EFFICIENCY AND CLEAN POWER GENERATION

GE has a multi-faceted approach with many options and capabilities that deliver high performance steam plant solutions for both GE and other manufacturers' equipment. Efficiency gains, for example, can lower fuel consumption and, in turn, emissions, while expanding power generation capacity. The biggest gains (on average 2.5%) in an operating coal power plant can be made through turbine and boiler upgrades. Steam turbine upgrades can result in substantial efficiency gains on existing assets of up to 10%. Also, by improving start-up processes, GE's OpFlex Steam Turbine Agility software can help to reduce start up fuels costs by up to 30%, depending on the operational state of the plant. Plants can also be upgraded with software solutions (on average 1% of efficiency) that interpret data from as much as 10,000 sensors located across a steam power plant.

In addition to improving efficiency, environmental control systems can help operators comply with the most stringent emissions regulations. GE offers various solutions to drive better performance of boilers, pulverizers, air quality control systems, ash handling systems, and auxiliary equipment, all leading to reduced pollutant emissions. Another interesting set of products involve mill upgrades and a digital "smart mill" solution that will help increase the range of coal quality that can be used in the boiler.

Figure 4 highlights some of the performance improvements that GE solutions can offer if implemented.

There are many examples of where significant performance improvements are available now. However, all major investments require power plant owners to develop a clear business case. This is discussed in the following section.

Figure 4: Improving the performance of a steam plant

BUILDING THE BUSINESS CASE

The life-cycle of fossil-fuelled power plants has traditionally involved a transition from focusing on improving efficiency and lowering emissions towards increasing flexibility. In the early years of operation, power plants could expect to run whenever available (base load), and there would be a direct payoff from improving efficiency in terms of avoided cost. As newer and more efficient plants came onto the system, the focus would turn towards flexibility and the ability to reliably stop and restart the plant as many times as possible. Ultimately, as operation became less frequent, the attention would be on providing capacity when needed by the system at the lowest cost and investing only in what was necessary to deliver availability during peak demand periods. When the earnings from these infrequent periods of operation no longer covered net avoidable costs, the plant would close.

The increasing volatility and unpredictability of the demand that must be met by fossil-fuelled plants changes this situation. Even the most efficient fossil plants that expect many hours of base load operation will still experience significant periods when there is no demand to meet and market prices are low or even negative. Also, some other plants can move from extended periods of infrequent operation to prolonged periods running flat out – for example, low wind periods or during winter. Finally, it is increasingly difficult to say when a plant is no longer needed, given the uncertainties in residual demand and new sources of flexibility.

A new framing is needed to think about investment which combines efficiency and flexibility. The new commercial imperative for power plant owners should be to focus on efficiently capturing as many periods of high price as possible and avoiding periods of low price. The case to invest depends critically on accurately forecasting running hours and market prices over all timescales and this, in turn, depends on the ability to forecast investment and performance of competitors and volume of residual demand (which can change very quickly over short timescales driven by variable RES output). Fortunately, there are many opportunities for power plant owners to significantly improve business performance and action by policy makers is necessary to create a reliable framework and further increase incentives to invest.

DECARBONISING THE POWER SYSTEM AT THE LOWEST COST

Decarbonising the power system means building new low carbon power generators, and it is likely that most of these will be variable renewables. Building these new assets is expensive, and it is important to get as much output from these as possible. Therefore, the power system must be adapted to ensure this renewable generation effectively contributes to meeting consumer demand and that 'curtailment' of renewable output is minimised.

These adaptations create so-called 'system integration costs' and will change over time the properties of the energy system. Additional 'back-up' capacity is required to ensure security of supply when renewable generation output is low. Also, unpredictability requires additional resources to balance supply and demand in real time. Supplementary costs will also be incurred from new network infrastructure, such as reinforcements to the transmission system to connect remote wind resources.

Analysis shows that system integration costs of renewables increases significantly when the overall flexibility of the system is low. However, it is also apparent that these costs remain low when a modern and flexible power system is created.[9]

New sources of flexibility are emerging (in particular, interconnector trading, storage and demand side response), but these will take time to cost-effectively provide the level of flexibility that is required. Therefore, this residual load will need to be met largely by existing thermal power generation for a significant time to come.

Consequently, avoiding curtailment of renewables is a key reason why system flexibility is so important. The more renewable output is curtailed, the more money must be spent on renewable generation capacity to achieve target reductions in carbon emissions.

The costs of inflexibility can be very high since it significantly increases the cost of integrating renewables onto the system. Unless these investments are made, there is a risk that the costs of decarbonising the power system will increase significantly.

Another area of concern is that some existing market mechanisms actually undermine the flexibility investments of the power system. Most notably, many governments across Europe have adopted so-called 'capacity mechanisms' with the intention of improving security of supply. These mechanisms reward generators for providing firm capacity at system peak and have two negative impacts on incentives to invest in efficiency and flexibility.

First, capacity mechanisms generally reward those assets that can remain open at the lowest fixed cost rather than those generators that have invested to improve efficiency or flexibility. Second, they lead to higher levels of capacity than would otherwise be the case, thereby supressing the price signal that would support a positive business case and encourage investment.

As the energy system changes, new markets must be developed to ensure generators effectively deliver the services needed. While it might have been sufficient in the past to focus on ensuring that adequate capacity was available to meet peak demand, this is no longer the case. The greatest threat to security of supply occurs when either demand is increasing to a maximum while renewable generation is reducing and, conversely, that demand is falling to a minimum while renewable generation is increasing. These new dynamic effects mean that the value will shift away from simply delivering capacity toward providing a broader range of system services.

The EU Commission has recognised the need to adapt markets and has recently proposed new measures in the 'Clean Energy for All Europeans' package to correct the deficiencies. The proposed changes to the power market design are largely addressed through re-casting the Electricity Directive and associated Electricity Regulation, and the changes can be grouped into three categories: market functioning, market integration and consumers.

Much of the package, when analysed, is devoted to creating a 'fair deal for consumers' and involves a range of measures to improve information, protect those who are vulnerable, and empower consumers to save money by improving the efficiency and flexibility of consumption. It is important not to assume that the active participation of consumers will emerge in time and at sufficient scale to provide the flexibility required by the system. Additional focus must be placed on helping existing generators to make the investments needed.

While these measures contain many positive features and place strong emphasis on improving overall system efficiency and flexibility, there is still a clear gap in failing to identify the value of the existing fleet of thermal power plants in creating a bridge to the future. There are ample opportunities to make significant improvements in system efficiency and flexibility now, but this will require policy makers to take further action.

[9] *https://www.e3g.org/library/plugging-the-energy-gap*

A POLICY AGENDA

We have already established the importance for existing fossil power plant owners to continue investing in the efficiency and flexibility of their assets. However, there are obstacles that are preventing this from happening:

- The uncertainty associated with market price forecasts and the challenges this creates in building an investment business case.
- The fact that some of the most significant costs of curtailment of renewable generation are not reflected in market prices and, therefore, the incentives to invest in flexibility are diluted.
- The use of market mechanisms that do not reflect the emerging challenges to security of supply and fail to support investment in efficiency or flexibility.

The policy agenda needs to focus on these issues. While there has been considerable discussion of the role of capacity mechanisms, the latest market design proposals from the EU Commission fail to address the underlying problems facing power plant owners in developing a business case for investments that would deliver much needed system services.

It is necessary to recognise that efficiency and flexibility are critical factors in ensuring a cost-efficient decarbonisation of the power system. These are too important to leave to the whim and volatility of the market – particularly given that price formation mechanisms are undergoing a process of change leading to outcomes that are riddled with uncertainty.

The EU has an important role to play in ensuring Member States implement the necessary solutions. ENTSO-es (European Network of Transmission System Operators) should be required in their Ten-Year Network Development Plan to clearly identify targets for system flexibility that are consistent with cost-effectively minimising renewable curtailment in line with agreed targets for renewable deployment. National TSOs should be mandated to ensure that the appropriate levels of flexibility are available and Member States should be required to report on progress towards delivering these targets as part of their National Energy and Climate Plans.

There are many policy levers available to Member States that will help incentivise investments in efficiency and flexibility (e.g. obligations on utilities, refinements to existing capacity mechanisms, new contracts with TSOs) and some that would benefit from co-ordinated effort at EU level (e.g. efficiency standards for industrial processes, grid code operational standards).

However, the critical objective remains - to reduce the uncertainty over future investment returns to help align the business imperative with system need.

CONCLUSION

The existing fleet of fossil-fuelled power plants is an important facilitator of change, and continued investment will support the transformation of the energy system in Europe. In particular, investments in efficiency, flexibility and cleaner power generation will keep the transformation on track and the costs low.

A range of technical opportunities now exist that can be implemented to deliver immediate benefits for plant owners, for consumers and eventually, for our society. These include both engineering solutions and digital technologies. Several power plant owners are already implementing these solutions across Europe.

While there might be clear and compelling business cases to support some investments, others will be more difficult to justify. This is despite the fact that in many cases there are clear system benefits. Policy makers should focus on issues that are obstructing the necessary investments from being made. Addressing these failings should be a policy priority that seems largely absent from the current debate.

Lastly, both individual governments and the EU have an important role to play. The EU should mandate ENTSO-e to identify the levels of system flexibility and Member State Governments have to ensure that the desired outcome is delivered cost-effectively. Indeed, they should have the freedom to choose those mechanisms that are most appropriate for their individual circumstances.

As our world progresses, and creation and consumption patterns evolve, we realise that the power systems globally, including in Europe, are on a new and exciting journey. But to ensure seamless succession and future success, it is vital to take into account all the factors that will impact this change. Accepting and believing in the long-term goal is the only way to ensure a prosperous, safe and financially viable bridge to our future.