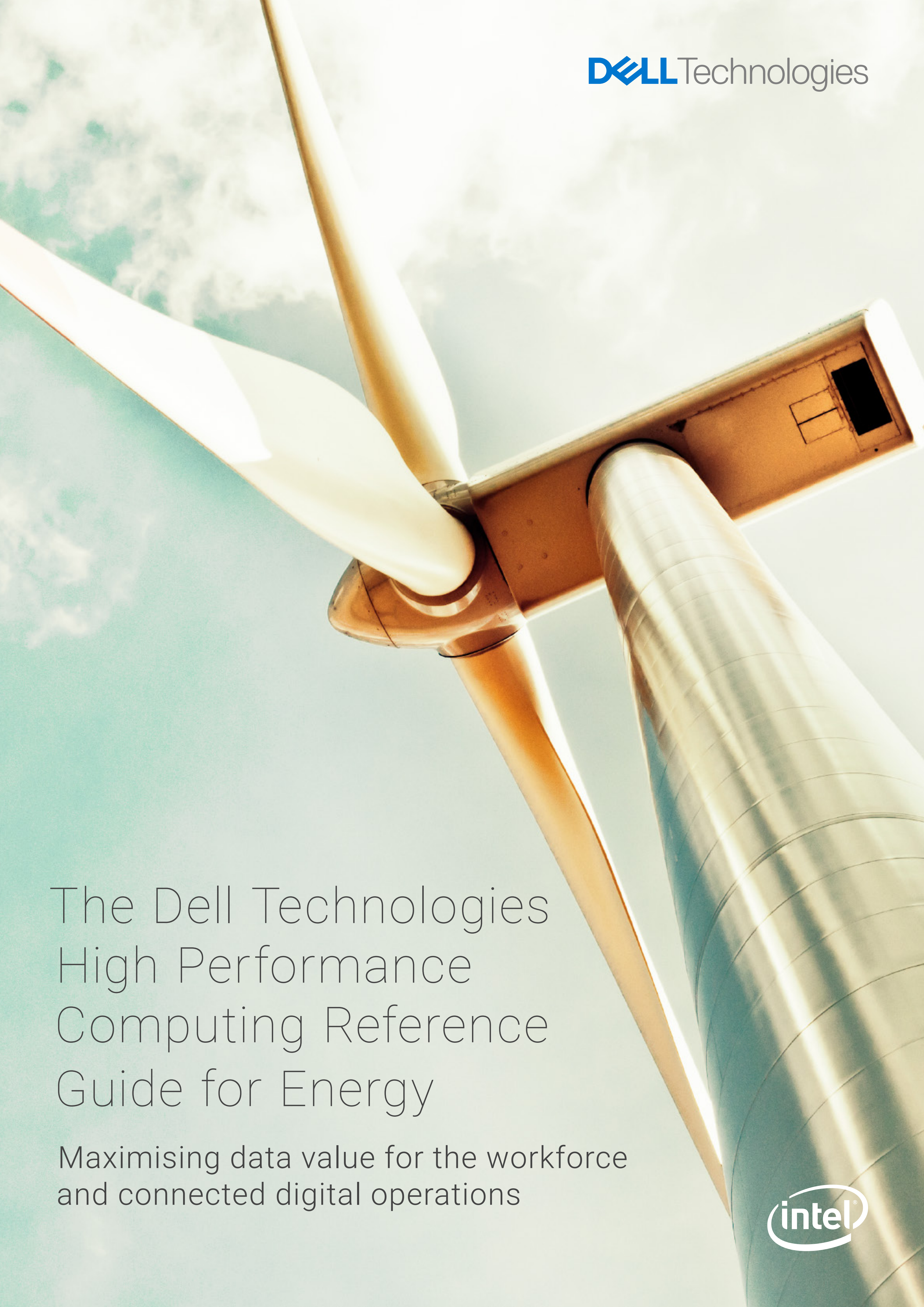

The Dell Technologies High Performance Computing Reference Guide for Energy

Maximising data value for the workforce and connected digital operations

About the author

Julian Alfred's career in Technology Business Development spans a series of disciplines from Application Development to Data Management & Analytics to IoT (Internet of Things). He has proven experience across multiple industries, including Oil & Gas, Electric Utilities (including Renewables), Financial Services and Retail, and in Solution Development and Sales Enablement go-to-market execution related to Cloud, Big Data & Analytics, Artificial Intelligence, Application Deployment through Converged/Hyper-Converged infrastructure, Connected Digital Ecosystems and AR/VR (Augmented and Virtual Reality).

More recently, Julian spent over five years in the Energy sector, focusing on Sales Enablement activity to support $1.6bn in annual global sales.

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Intended Audience

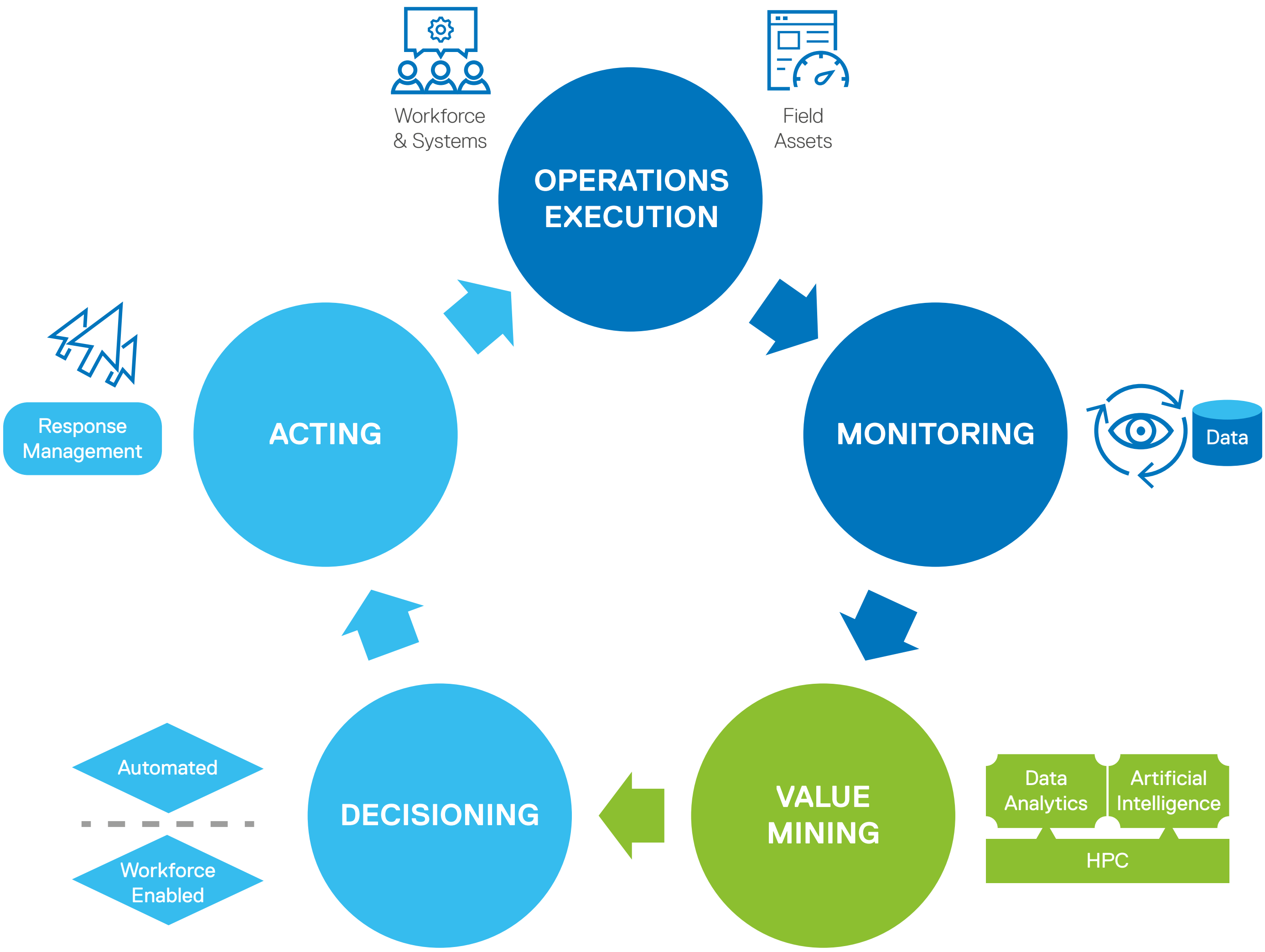
- Energy C-suite focused on Field Operations, Workforce Management, Industry Compliance and Customer Success
- Energy Leaders responsible for Data Analytics, including Artificial Intelligence (AI) initiatives
- Energy Technology Leaders responsible for planning and delivering resources for HPC initiatives

Whether the Energy Industry recognises it or not, Oil & Gas and Electric Utility companies are operating in an era where success or failure lies in their ability to achieve **TechQuilibrium**.

TechQuilibrium, as defined by global research and advisory firm Gartner, is 'the balance point where the enterprise has the right mix of traditional and digital capabilities and assets to power the business model needed to compete most effectively in an industry that is being digitally revolutionised'.

Unquestionably, the Energy Industry is experiencing a digital revolution, or to more accurately describe the moment, it is an empirical necessity to digitally revolutionise the Energy Industry in order to successfully power local, regional and global economies. Failure to achieve this state of digital transformation has serious ramifications not only for the Energy industry itself, but for every other industry, and ultimately for human progress.

This HPC Reference Guide for Energy demonstrates the importance of successfully leveraging general Data Analytics, Artificial Intelligence (AI) and High Performance Computing (HPC) during the digitalisation journey, using scalable solutions available today. More specifically, by way of a Virtuous Circle of Operational Efficiency, the guide also discusses the value of defining HPC initiatives in a holistic manner that leads with business objectives rather than technology prowess, and uses sound economic deployment principles to secure practical implementations.

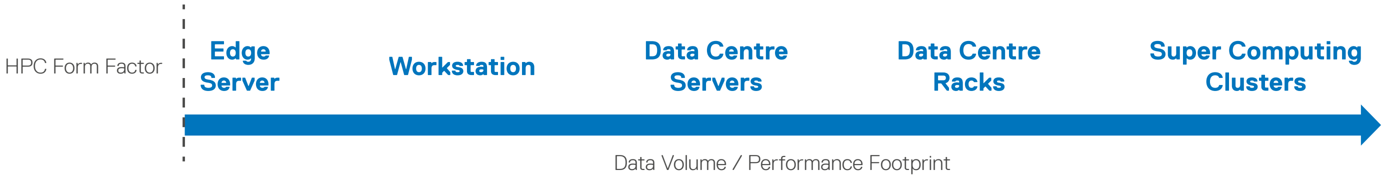


Energy Industry Virtuous Circle of Operational Efficiency

Modern HPC is more than just Supercomputing Clusters

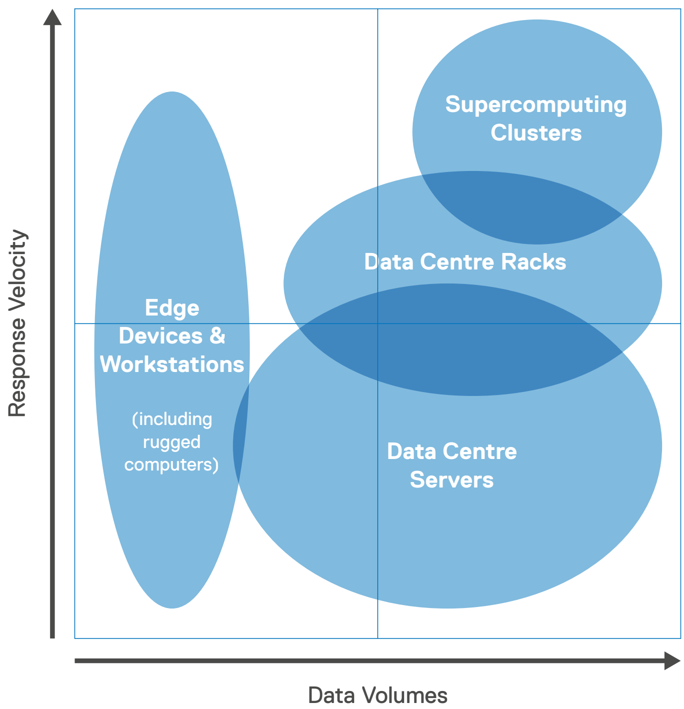
Recent advances in compute, networking and storage technologies have put High Performance Computing (HPC) — and thus Data Analytics and Artificial Intelligence (AI) — within reach of more Energy applications than ever before. HPC solutions can significantly impact the success of Energy businesses, whether they are looking to automate electricity substations, dynamically load balance ever more complex power grids, forecast electricity demand, improve hydrocarbon extraction with less invasive techniques, anticipate customer sentiment or to significantly increase operations and workforce safety through predictive analytics.

The modern-day discussion about HPC is no longer limited to initiatives driven by huge clusters of supercomputing capacity. It has become a much more holistic outlook that explores how Servers, Networking, Data and Workstation technologies can be combined intelligently to convert the potential value held within data into kinetic business and operational activity that spans a spectrum of use cases and response velocities.



HPC Form Factor Spectrum

At Dell Technologies and Intel®, we understand the analytics-oriented IT needs of the Energy Industry, and offer modern HPC solutions that make adoption faster, simpler, and more collaborative. We deliver a choice of flexible and scalable HPC solutions for Energy businesses of any size, with purpose-built servers, cluster management software, edge devices, and workstations that are complemented with advanced cloud computing and security systems to address a wide range of use cases.



HPC Form Factor Matrix

The Dell Technologies edge devices and workstations simplify the deployment of HPC resources beyond the core data centre into energy field assets where expected response velocities are high and the amount of data to be processed per analytics run is relatively small or is based on real-time streaming. Where the volumes begin to approach petabyte levels, data centre clusters based on servers or racks offer the level of scalability expected for parallel computing based on SLURM, or for container-based analytics built on Kubernetes. And finally, these solutions help companies:

- Solve the most complex problems by enabling them to execute highly complex and compute-intensive tasks in real-time, as well as train and execute AI models to gain the insights that drive innovation
- Accelerate time to results by dramatically simplifying the design and configuration of HPC systems without compromising on performance, security or scalability
- Reduce the risk of HPC and AI adoption by facilitating knowledge transfer and test drive sessions in our global HPC innovation network of labs

Dell Technologies and Intel® in Energy

The world faces environmental, healthcare, economic and political challenges that have no modern precedent. At Dell Technologies, we are committed to empowering individuals, organisations and communities with technologies that meaningfully contribute solutions to many of these challenges. We create technologies that drive human progress.

Dell Technologies has been working with Electric Utility and Oil & Gas companies on driving innovation in the Energy industry for more than 20 years. Together with Intel® and an innovation ecosystem of partners and customers, Dell Technologies is delivering digital transformation focused on areas such as electricity grid modernisation and optimised hydrocarbon exploration and production solutions from the edge to the core data centre. These solutions are not only directed at improving the operational efficiency of computer systems and physical field assets like electricity substations, windfarms, and Oil & Gas drilling platforms, but also at increasing workforce productivity and safety. Data Analytics, Artificial Intelligence (AI), High Performance Computing (HPC) and Cyber Security form the cornerstone of our digital transformation strategy for the Energy Industry.

Within the Dell Technologies business itself, electricity makes up the largest proportion of our facility energy use, and we're committed to buying from renewable sources. We are regularly ranked as a Top 50 purchaser of renewable energy in the U.S. EPA's Green Power Partnership program and we incorporate onsite solar installations at several locations. We're also looking to improve the energy intensity and power consumption of the data centres we manage and support. These kinds of initiatives also help to reduce the overall cost of running increasingly demanding workloads that are HPC-driven.

Electricity production, delivery and use are getting more efficient and sustainable with the Internet of Things (IoT). IoT-enabled sensors, devices, and data analytics give intelligence to equipment and deliver operational insights, enabling energy companies to dynamically manage assets, decrease maintenance and transmission costs, and improve worker safety. Intel®'s interoperable, secure, and scalable industrial processors and software components are powering the advance of smart energy.

As power generation shifts from the reliance on older, centralised plants powered by fossil fuels to more distributed, renewable sources like solar, wind and battery storage, advanced controls and analytics are needed to:

- Better maintain both the legacy plants and newer power sources
- Ensure regulatory compliance
- Avoid environmental and costly failures
- Deliver clean energy reliably

Dell Technologies and Intel® deliver Industrial IoT, Data Centre and Workforce mobility solutions that are leading the way. We also provide solutions that enable Oil & Gas companies to extract hydrocarbons more responsibly by supporting use cases such as HPC-driven reservoir simulation and predictive analytics for field asset optimisation and safety. By working together, Dell Technologies and Intel® integrate complex technologies into simplified deployment platforms that enable an accelerated, reliable and safer digital transformation of the Energy Industry.

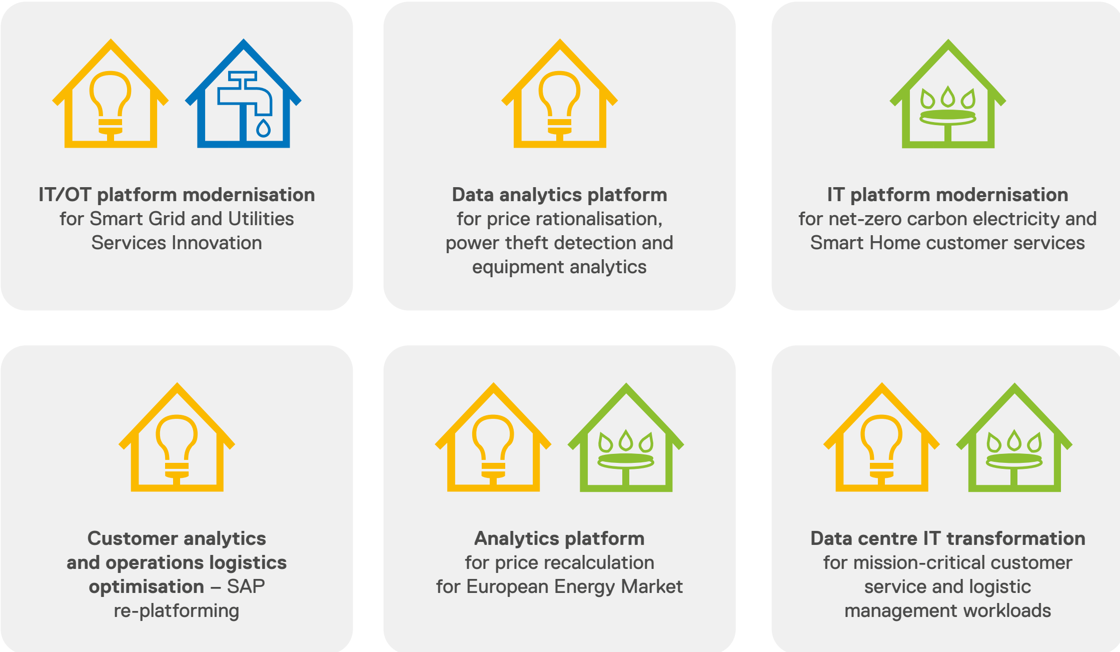
Propelling Oil & Gas Exploration and Production – Customer Example

In 2019, Italian multinational Oil & Gas company Eni S.p.A began the implementation of HPC5, one of the world's greenest and most powerful High Performance Computing infrastructure, utilising over 1800 Dell EMC PowerEdge Servers each with two 24-core 2nd Generation Intel® Xeon® Scalable Processors – Gold 6252, and capable of a peak processing power of 51.7 petaflops. When combined with the existing Super Computing system HPC4, the peak computational capacity of the Eni infrastructure totals 70 petaflops – 70 million billion mathematical operations performed in a second.

In June 2020, HPC5 was ranked sixth on both the TOP500 list most powerful supercomputers in the world, and on the GREEN500 List for energy efficiency. With just 1W of electricity it can perform almost 20 billion operations per second, enabling the practical and rapid use of extremely sophisticated in-house algorithms to process subsurface data. Geophysical and Seismic data collected from around the world is sent to HPC5 for processing to develop extremely in-depth subsurface models, to more accurately determine what is hidden below.

Accelerating Digital Transformation Initiatives in Energy Utilities

As the Energy market continues to evolve, Electric Utility companies are attempting to transform their operations based on a business model that is a highly responsive, interactive, and data-driven exchange between the consumer and the utility. Dell Technologies provides a comprehensive portfolio of products, solutions, services, and partnerships needed for Energy Utility companies to become agile and dynamic producers and suppliers of increasingly clean and efficient resources. We understand that the priorities for Energy Utility companies will be varied, so our approach takes the maturity stage of each company into consideration, to help define digitalisation strategies with starting points that minimise operational disruption and maximise time-to-value. Below are examples of the types of initiatives Dell Technologies is engaging with Energy Utilities today, ranging from multi-million-dollar platform modernisation projects to enable smart grid systems and predictive maintenance in the field, to core data centre high performance analytics for energy price rationalisation, logistics optimisation, and customer service.



Dell Technologies Energy Utilities Engagement Examples

Investing in the Exascale future of HPC

According to the 2018 IDC White Paper 'Data Age 2025: The Digitisation of the World From Edge to Core' (sponsored by Seagate), the world's data growth is predicted to reach 175 zetabytes by 2025. To adapt to significantly larger data sets and compute-intensive analytic processes of the relentless age of digitalisation, data scientists regard exascale systems, capable of performing one quintillion (10^{18}) calculations per second, as being the necessary future of HPC.

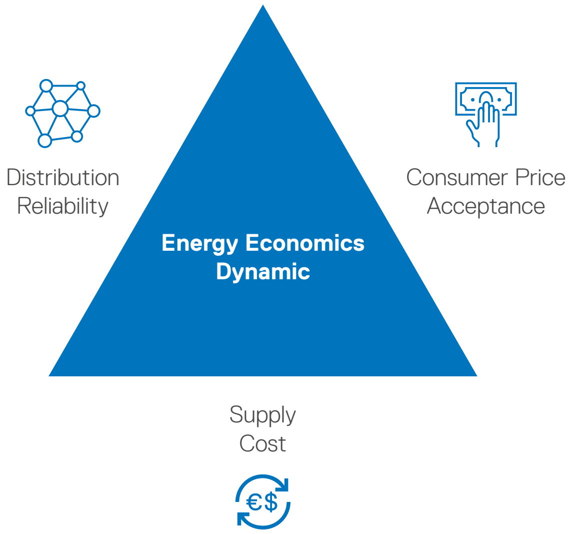
Dell Technologies has collaborated with Intel® and the University of Cambridge, which houses one of the United Kingdom's top performing supercomputers, to launch the Open Exascale Lab. Dedicated to facilitating innovation and investigating emerging exascale technologies, the lab enables the world's most advanced technology leaders and experts from multiple industries such as Energy, Healthcare and Manufacturing to collaborate on next-generation HPC systems. Dell EMC servers, networking and storage equipped with the latest Intel® technologies power this environment.

Dell Technologies, the University of Cambridge and Intel® have already collaborated on one of the world's fastest open source HPC storage solutions that has improved time to discovery and insight by alleviating performance bottlenecks between compute and storage.

Energy-driven Global Economic Success

About a decade ago, energy was a commodity that commercial and residential consumers alike largely took for granted, similar perhaps to the not unreasonable expectation that when we turn on a tap in a kitchen, bathroom or garden, we expect water to flow immediately.

At the flick of a switch, a light comes on. We start our car and expect an engine to roar to life, so long as there is fuel in the tank, or sufficient charge in the onboard batteries if you were eco-friendly enough. Many paid little or no attention to the processes by which energy is produced on a daily basis, but almost everyone was interested in the cost of procuring it.

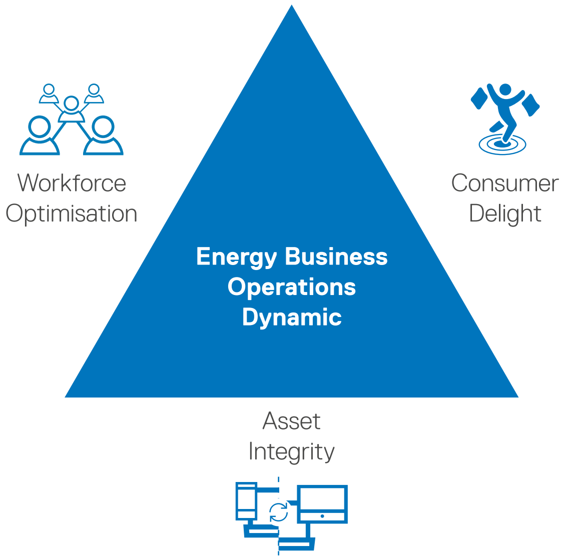


Energy Economics

Today, energy forms the backbone of almost every aspect of daily life. The mobile phone user is concerned more than ever with battery life and recharge time, as the reliance on apps increases at a relentless pace – from email to digital social interactions, from banking to healthcare, from transportation to video conferencing and group collaboration sessions, from ordering deliveries to booking hotels and restaurants. The mobile phone is a long, long way from being a device primarily for making one-to-one calls.

At the other end of the spectrum, businesses recognise the value of treating energy with an aptly labelled 'renewed respect', because doing so offers a new frontier in which companies across all industries could simultaneously reduce operational costs, facilitate the shift towards a cleaner global environment, and improve the general attractiveness of their brand. Bringing energy out of the shadows and placing it front and centre in strategic planning sessions offers companies a significant opportunity to take more control of how their businesses function, by potentially chipping away at the dependency on external services in a way they cannot, for example, do with telecommunications. Solar panels could be installed on the roofs of office buildings, near-line wind turbines erected on appropriately zoned land, and industrial scale battery technology used to store excess energy produced by these private or community renewable sources either for later self-use, or to sell on to the external grid when rates are favourable.

But businesses and residential consumers are not the only potential winners. Energy companies can share in this new world, and remarkably so through symbiotic relationships with consumers.



Business Operations

To better understand this new dynamic, we need to inspect the topic of Energy not only from the point of view of the traditional Energy industry definition which is often summed up in drilling operations or electrical grids, but also in terms of the cross-industry global economic lifeblood that it is. Without Energy, human progress ceases to be transformed by technology.

As a result, Energy companies carry a responsibility of untold magnitude for global economic success or failure – whether humanity thrives or becomes extinct, whether one nation can feed itself or starve, whether children in one city can receive a full education or grow up in ignorance, and whether the lifespan of a community is stilted because of a lack of healthcare infrastructure. All these things and more require energy. Very little survives without it.

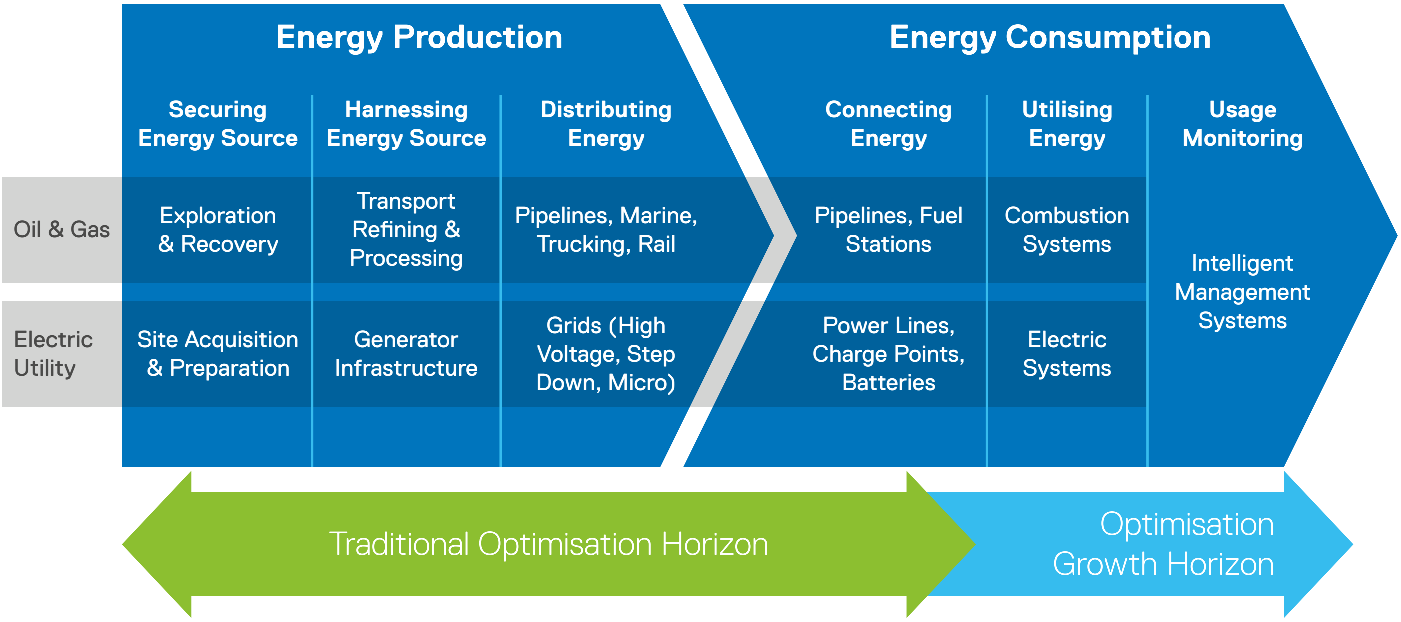
The Digitalisation of the Energy Eco-system

The Energy dynamic today is not as simple as generally thought, where the main thrust of activity is portrayed as the shift from fossil fuels to electricity produced from renewable sources. The reality is much more subtle.

Firstly, there remains much investment directed at powering industries using combustible fuel. This includes the production of more carbon efficient derivatives from fossil fuels, converting waste into sustainable aviation fuel, and creating synthetic fuels using renewable energy, hydrogen, and carbon dioxide. It is interesting to track which of these innovations actually make a meaningful impact on reducing the global carbon footprint, and which are efforts to prolong the life of energy sub-sectors largely perceived as declining. In reality, there are still types of consumption systems where the deployment of electric power to replace combustible fuels is not currently a practical or economically viable option – for example an electric aircraft engine that could endure the length of a commercial transatlantic flight using a renewable power source.

Nevertheless, traditional Oil & Gas businesses are seriously thinking about whether they can and should transform themselves into Energy enterprises that continually shift their operational interests away from fossil fuels to renewable energy. At least one company, Ørsted, has already made this dramatic change. Over a decade ago when the Danish company was known as Dong Energy, 85% of the company's heat and power revenues came from coal. But in 2009, the company announced an initiative to turn that approach on its head with a bold strategy to generate 85% of heat and power from renewable sources by 2040. The reality was better than planned, achieving its target more than two decades ahead of schedule. By 2019, Ørsted was the world's largest producer of offshore wind energy, raising its renewable generation share to 86% (see Ørsted's 'Renewable Energy Transformation' interview conducted by McKinsey & Company). Other Oil & Gas companies are already on the transition path, and will need to rely heavily on digitalisation and the associated level of automation and analytics to survive in an increasingly competitive Energy industry.

Secondly, the Energy Industry is often condensed into two areas – Energy Production and Energy Consumption. A third important dimension is Efficiency, on both the Consumption and Production sides.



Efficiency Zones for Digital Innovation

Traditional Optimisation Horizon

The three dimensions of Production, Consumption and Efficiency may appear to be obvious at first, but if you look at where Energy companies traditionally focus efficiency initiatives, our eyes are generally drawn to the Energy Production side, where it is well-known which areas need to be optimised, for example:

- Finding more efficient ways of extracting oil and gas, or picking the optimal location for a hydro-electric plant, windfarm or solar array
- Using automation of field equipment to maximise operations uptime, and to improve incident prevention and event responsiveness
- Providing the field and office-based workforce with information regardless of their location
- Running fine-tuned logistics across operations

However, on the Consumption side, it is a slightly newer frontier beyond supply side inventory management, electric grid optimisation, incident diagnostics and workforce response agility. There is plenty of room for innovation, particularly for Electric Utilities.

Optimisation Growth Horizon

There are other so-called beyond-last-mile or behind-the-meter opportunities where Energy companies are able to not only grow their revenues, but also perhaps more importantly, to retain their customers with embedded value-add services. In fact, energy companies offer online quick-check services to help businesses and residential communities to quantify their energy spending and ecological footprint ahead of services engagements. There may be regional regulations that limit the extent to which an Energy company could offer full-chain services to customers, but from a consumer point-of-view, access to these value-add services is hugely beneficial – in other words, there is a market.

Perhaps the most recognised and initially counter intuitive example of Energy companies offering beyond-the-last-mile/behind-the-meter services is where an Energy company offers to:

- Digitalise and monitor the energy consumption for industrial and commercial customers
- Analyse energy usage patterns at a granular level
- Control equipment using automation to reduce the overall energy bill, shifting the needle towards carbon-neutrality – all without negatively impacting retail revenues

There is also plenty of opportunity beyond this bold but obvious case, where creative energy companies can use some lateral thinking to cross-pollenate industries with technologies. For example, a large UK supermarket retailer was not only looking to reduce its carbon footprint by leveraging renewable energy resources such as solar panels onsite, but to also push the boundaries of previously considered mature technologies such as refrigeration. New technology created originally by Aerofoil Energy and Williams Advanced Engineering to divert air over and around race cars to allow them to maximise performance suddenly seemed applicable to the supermarket retail business. It was discovered that the technology could also be used to help prevent cold air from bleeding away from fridge cabinets by directing it back into the fridge to save energy, keeping aisles warmer and reducing food waste. You can argue whether this is a retail industry initiative or an Energy industry initiative, but what is clear is that the conversation about energy cuts across all industries in a deep and significant way, and that suggests that Energy companies have a new growth horizon to capitalise on.

To summarise, it comes as no surprise that in order to fulfil the optimisation potential right across the Energy industry, reliably connecting all aspects of production and consumption at a granular level is necessary, and requires the collaboration of industry leaders, including those in big data, analytics, cloud computing, telecommunications and security.

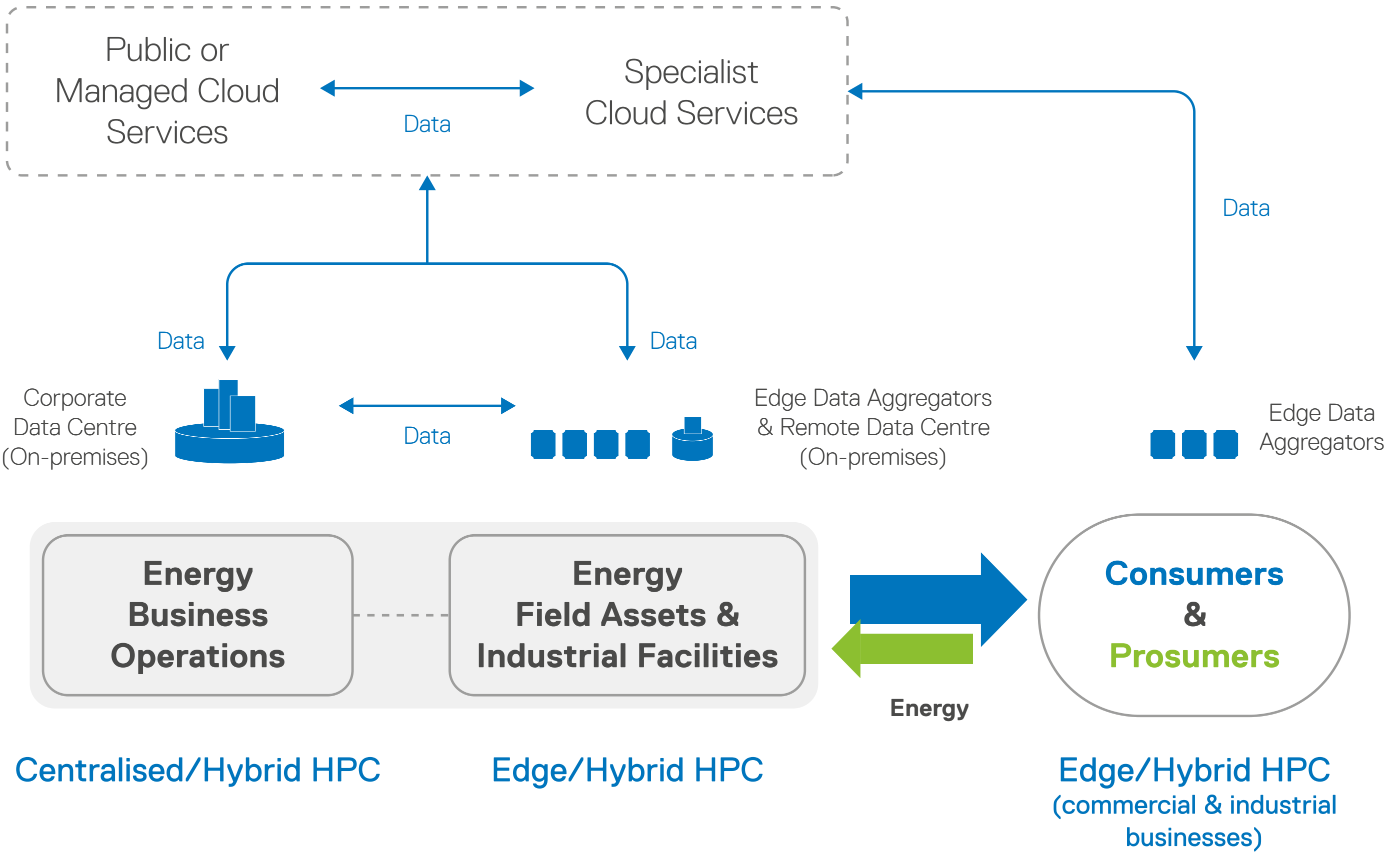
But the engine that is required to make this digitalisation of the Energy industry work is HPC, which Dell Technologies and Intel® excel at.

HPC is Essential for Successful Digitalisation

It is well understood that in order to manage the complexity of the hydrocarbon and electric energy value chains, digitalisation of processes from energy source to energy consumption is paramount. The Energy Industry continues to deploy sensor technology with increasing granularity into legacy infrastructure, while also replacing equipment with newer sensor-ready products where cost effective. As a result, there is no shortage of data that can be leveraged to optimise operations, but one of the biggest challenges to digitalisation is the speed with which data can be collected, processed and value extracted and applied back into workstreams. HPC coupled with scalable data management solutions is therefore essential for the success of digitalisation.

As the scale of energy operations increases with rising demand and supply points, relying on centralised analytics is rapidly becoming less effective as incident prevention and response times degrade due to data lag between the edge and centre, and a lack of field workforce skills to compensate. Decentralised High Performance Computing addresses this issue in large part as it enables more analytical workloads and automated decisions to be taken nearer the source of the systems that require attention. This is a huge but necessary undertaking, and is an area that Dell Technologies, Intel® and their partners work with energy companies to simplify in at least three key dimensions:

1. Orchestration of elastic IT resources through cloud computing for separate or hybrid implementations of on-premises and managed data centres, edge computing, and resources from public and specialised cloud services
2. Security of data at rest or being streamed, as well as access to supporting computing systems for analytics
3. Deployment of HPC in challenging environmental field conditions (e.g. temperature, vibration, geological and chemical)



Distributed HPC for Energy

As the figure above shows, there are three primary components around which decentralised HPC takes place:
1) Energy Business Operations
2) Energy Field Assets (e.g. Oil & Gas drilling platforms and pipelines, Electricity generation sources and distribution grids) and other Industrial Facilities (substations, refineries)
3) Customers in the form of Consumers (users of energy) and Prosumers (producers of energy, usually from private renewable energy sources)

Note the Edge/Hybrid HPC factor, which represents an opportunity for Energy companies to provide energy management services to commercial and industrial businesses as highlighted in the previous chapter on The Digitalisation of the Energy Eco-system. In subsequent chapters, we will discuss specific Energy use cases that require HPC, as well as their solutions.

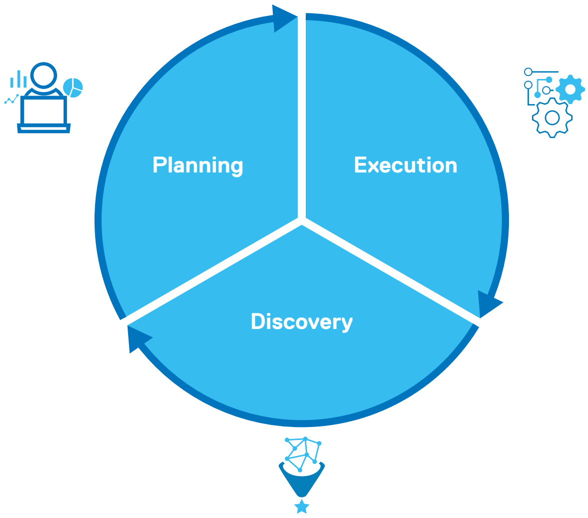
Organising Energy Businesses to Maximise Success with HPC

Almost every division from field operations through to marketing analytics within an Energy business can enjoy substantial paybacks from deploying HPC. Far from being a luxury, it is the necessary ingredient in a digital transformation process which facilitates the rapid extraction of actionable insights from data flowing through the organisation. Like the early data management and cloud computing technology adoption of the past, the success of HPC will be spotty if it is not treated with respect. Without an overarching plan, each division may attempt to explore, implement and manage their own HPC initiatives, resulting in human resource and financial inefficiencies.

Implementing an HPC strategy does not require a rigidly prescriptive centralised deployment of HPC resources across an Energy organisation, but having a plan enables easier identification of the areas where greater economic benefits could be had through the sharing of HPC infrastructure and data science expertise. In fact, in order to understand how to approach the use of HPC, a company needs to qualify and quantify what analytics expertise in the form of data scientists it already has, and to then decide how much it is prepared to either grow or outsource that expertise.

Step 1: Categorisation

The first step to defining an HPC strategy is to categorise analytics initiatives into three buckets – Discovery, Planning and Execution.



Discovery	Looking for patterns, extracting insight, making sense of operations
Planning	Creating models and running simulations to develop cost and resource efficient plans
Execution	Monitoring operations across a spectrum of data velocities to increase response agility at the edge or core using deployed models

Discovery

The **Discovery** category refers to the kind of HPC workloads where the business is seeking to uncover patterns or trends about which little or nothing was previously known. An example in Oil & Gas is for advanced seismic processing such as 5D Seismic Interpolation, where AI techniques can be used to improve the quality of previously acquired seismic datasets that may contain gaps. Reshooting seismic data is an expensive process, so if analytics can be used to fill in the missing pieces of seismic data to create a more complete view of the subsurface, the ROI on executing such a workload is very strong. In Electric Utilities, detailed grid supply and consumption data can be leveraged to understand what the common factors were for repeated outages in a particular area. Therefore, the outcome value of Discovery is to be better informed for Operational Planning.

Planning

The **Planning** category refers to HPC workloads where the learnings from Discovery are used to create more robust, safer and cost-effective energy projects. In Oil & Gas for example, Discovery information about the subsurface can be used to create models and run simulations in order to determine the optimal number and placement of rigs needed to maximise a reservoir, as well as the number of field workers required to run operations. From an Electric Grid point of view, Discovery information would be invaluable to better plan how to configure electricity distribution resources to supply a new development of residential accommodation for an additional 20,000 people by running simulations and creating models.

Execution

Finally, HPC has a place in **Operations Execution**, ranging from use cases related to operations monitoring, to the rapid processing of real-time sensor data so that timely action can be taken either in an automated way or by better informed manual decisions. The aim is to use HPC to continuously optimise Energy businesses to maximise systems uptime, to bring unplanned downtime and outages to near zero and to run systems efficiently with the least amount of carbon footprint.

Step 2: Zone Prioritisation

The Categorisation buckets can be further refined into prioritisation zones that will later be used to map out what specific HPC resources will be required, where they will be deployed and how they will be managed. The use of the deployment Zones will be explored further in section 'HPC Technical Architecture Considerations and Best Practices'.

HPC Prioritisation Zones

Incubation Zone

The **Incubation Zone** relates to analytics activity aimed at Discovery. The HPC resources required are usually ad hoc in nature, which makes provisioning them from a cloud-based environment attractive. It is important to point out that 'cloud' does not automatically mean 'public cloud'. It also includes the option of provisioning resources from private cloud environments which may be managed internally, or by a third party on behalf of the Energy company. Additionally, choosing to include an Incubation Zone in the HPC strategy typically requires an investment in data scientists.

Transformation Zone

The **Transformation Zone** uses HPC resources to promote promising projects from the Incubation Zone to fine-tune and operationalise them for the Performance and Productivity Zones. The HPC resources required are typically more substantial than those deployed in the Incubation zone and will likely be provisioned for longer periods of time to not only create models to be deployed into the Performance and Productivity Zones, but to also continually adjust and refine them as learnings from production use are ploughed back into their designs.

Performance Zone

The **Performance Zone** uses HPC to drive operational efficiency and focuses on workstreams directly related to physical assets such as Predictive Maintenance, Electric Grid Load Balancing and Oil & Gas Drilling Optimisation. These HPC resources tend to be distributed to maximise overall operations agility, with resources deployed both at the edge where operating conditions require compliance with rugged environmental regulations and in core data centres where resiliency in terms of systems uptime and security are critical.

Productivity Zone

The **Productivity Zone** leverages HPC to enable the field workforce to monitor operations and make decisions more effectively, and for customer services personnel to understand current and future consumer needs to increase market response agility. The HPC requirements for the Productivity Zone share similar characteristics with those of the Performance Zone since both zones are in the Execution category, but the emphasis in the Productivity Zone is on using HPC to empower the workforce with timely insights to facilitate better decision-making. The net effect of HPC in the Performance and Productivity Zones is increased operational efficiency and customer satisfaction, both of which impact the profitability and market position of an Energy company.

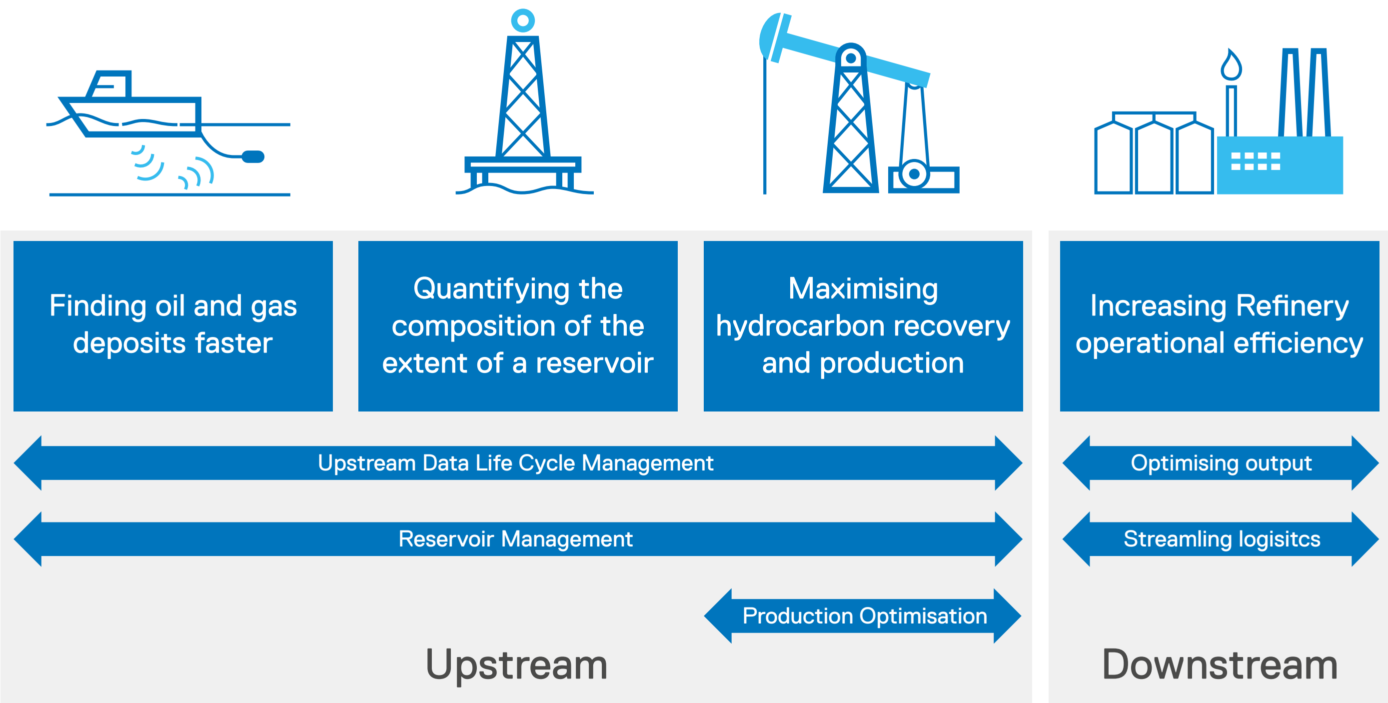
Zone Prioritisation and HPC

Because the Transformation, Performance and Productivity Zones are so closely related, the Zoning Prioritisation concept can assist in deciding whether a unified HPC architecture may help provide lower TCO when compared with running multiple HPC clusters. With a Unified HPC approach, resources can be provisioned on-demand to reduce the amount of idle time of computing resources, which is likely to occur with a siloed HPC resource approach.

Energy Use Case Examples for HPC – Oil & Gas

Particularly in the exploration and production phases, HPC is no stranger to the Oil & Gas industry. Large volumes of seismic acquisition data are processed relentlessly in an attempt to locate, accurately quantify and qualify the hydrocarbon content in reservoirs discovered in the subsurface before recovery operations are commenced. As acquisition data is mainly unstructured and can easily reach petabyte levels for one potential oil and gas field, seismic processing activity can only be completed within a meaningful timescale by using HPC and appropriate data management strategies.

Although the Oil & Gas industry has been using sensor technology for decades to collect data from field assets to help optimise drilling and production operations, it was not until the severe fall in oil prices during the mid-2000s that wide-scale digitalisation across the industry accelerated. This is in part due to the rise of Industrial Internet of Things (IIOT) technology that enabled more sophisticated edge-to-core data lifecycle management and HPC computing to be integrated directly alongside field and refinery environments. This new phase of connectivity facilitated a streamlining of processes in the Oil & Gas Upstream sector for optimising production during drilling and recovery operations, as well as in the Oil & Gas Downstream sector for improving refining output and logistics.

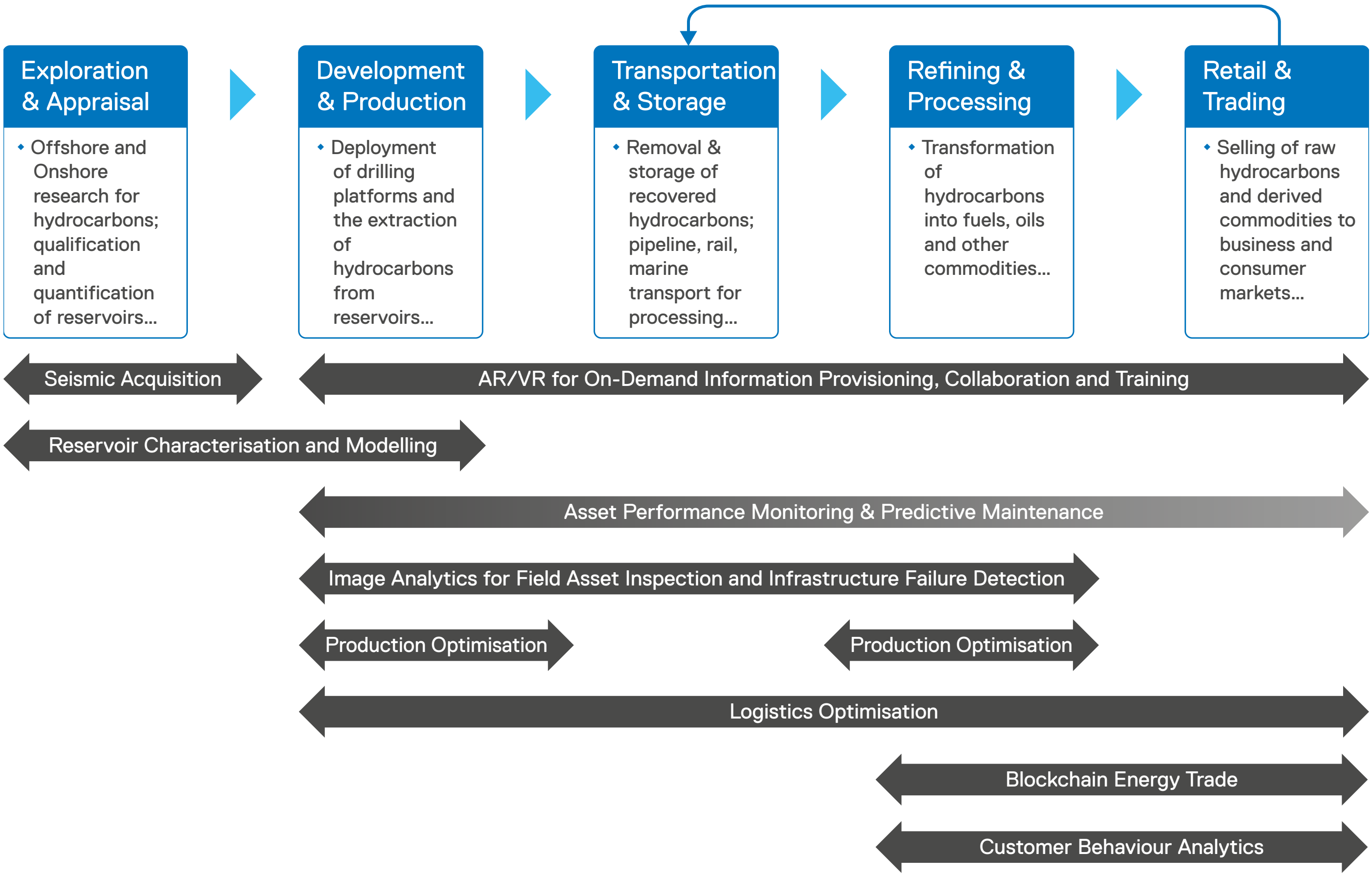


Key Oil & Gas HPC solution areas

The companies that quickly and successfully adopted the connected digital operations approach were able to restructure their businesses to survive the new lower oil price economics through increased automation, and experienced greater operations agility by making better decisions faster with improved data-rich analytics.

Today, digitalisation strategies in the Oil & Gas industry have expanded and deepened to cover almost every aspect of the hydrocarbon value chain, so it is worth decomposing the value chain to a granular level before mapping important HPC-oriented use cases across them:

1. Exploration & Appraisal
    - Searching for hydrocarbons offshore or on land using seismic surveys to produce detailed images of the sub-surface
    - Assessing sub-surface data, and drilling test wells to determine the presence and extent of hydrocarbons
2. Development & Production
    - Planning the most effective way of recovering hydrocarbons safely and cost effectively
    - Extracting hydrocarbons from the sub-surface
3. Transportation & Storage
    - Holding recovered hydrocarbons safely prior to trading and refining
    - Removing recovered hydrocarbons safely and efficiently from field locations
4. Refining & Processing
    - Converting recovered oil and gas into useful products such as petrol, diesel, jet fuel, asphalt, lubricants, plastics, fertilisers, anti-freeze, pharmaceuticals and cosmetics
5. Retail & Trading
    - Distributing and selling raw hydrocarbons and by-products of the refining process to resellers or directly to consumers



Example HPC Use Cases for the Oil & Gas Industry

Seismic Acquisition

One of the primary activities conducted in the Exploration and Appraisal stage in the hydrocarbon value chain involves directing sound waves at the subsurface and creating an image of the geology based on reflected waves captured by sensors. This seismic acquisition process is expensive, particularly for offshore exploration, but the potential value waiting to be unlocked from the data could be lucrative if it suggests the presence of significant oil and gas reservoirs.

The process of qualify and quantifying what may be in the subsurface is typically conducted by geoscientists using software that is often data centre bound and occasionally accessible remotely using virtual desktop technology. Therefore, seismic data captured during the acquisition process needs to be transferred from the seismic marine vessel or truck and shipped to geoscience facilities. However, if subsequent tests reveal poor data quality due to magnetic and acoustic interference or post acquisition data corruption on board the seismic vehicle, the survey will need to be repeated if a meaningful assessment of the potential oil or gas field is to be completed. The cost implications of doing this are of course significant, but there are also setbacks in terms of planning future drilling operations and scheduling heavily utilised oilfield services.

As a result of this inconvenient challenge, seismic acquisition companies are increasing the amount of HPC-driven data quality testing executed onboard the seismic vessel so that if data quality issues are identified, the cost of reshooting the seismic images is significantly less, given the vehicle is already onsite.

Additionally, seismic acquisition companies are focusing on improving their service levels by shortening the time it takes to shoot and deliver seismic data to geoscientists. Traditionally the solution was primarily logistics-oriented, with a heavy dependency on the rapid transport of tapes. However, if data could be safely transmitted wirelessly from seismic vehicles by satellite or by other digital means, delivery times can be significantly slashed and the time-to-value for geoscientists shrunk. Lossless data compression technology integrated with seismic data management platforms such as Dell EMC PowerScale scale-out NAS (Network Attached Storage) and rugged Dell EMC PowerEdge HPC servers enables sophisticated quality checking (QC) processing to be executed on seismic vehicles to ensure that data is both validated and made compact prior to digital transmission. (See how Dawson Geophysical collects complex seismic data at a vast scale, processes information centrally and hands projects to Oil & Gas clients faster using Dell EMC PowerScale (Isilon) storage and PowerEdge servers).

Reservoir Characterisation and Modelling

Acquiring seismic data is an expensive process, but even costlier is drilling a dry hole, so careful but rapid analysis of the data is critical. Processing seismic data is typically an iterative exercise, requiring specialised software from industry ISVs (Independent Software Vendor) organisations in companies like Schlumberger, Halliburton Landmark, IHS Markit and Emerson. It is also important to remember that locating what looks like a significant reservoir of oil and/or gas is only part of the challenge. It has yet to be extracted from the subsurface.

Once a reservoir has been identified, figuring out how to get to it economically is crucial. How many layers of rock exist between the surface and the hydrocarbons? Can we bypass the rock by drilling horizontally from an offset location? Are their significant amounts of sub-salt to deal with? How will rock porosity affect the physics of the reservoir once drilling commences? What is the environmental impact of employing fracking techniques to release natural gas? Can our best helicopters make the roundtrip from an onshore base to a potential platform out at sea? The answers to these and many more questions require complex analytics to be applied to large volumes of unstructured data.

A modern HPC portfolio like that offered by Dell Technologies with 2nd Generation Intel® Xeon® Scalable Processors enables large data sets to be processed significantly faster in fewer cycles and with less reprocessing than traditional practices. This makes it more viable to use larger more detailed data sets for seismic processing and to carry out advanced analytics such as Large Volume Seismic Interpolation, Seismic AVO Analysis and 5D Seismic Processing.

Visualisation

Turning largely technical raw seismic data into something that is easily understood and closely associated with a business context involves more than important 'crunching the numbers'. By also fully utilising data science workstations such as Dell EMC Precision workstations with powerful graphics processing units and other types of accelerators from industry leaders like Intel®, data scientists can generate clear interactive 3D visuals that are easy to manipulate. With better visuals, project collaboration is enriched as the data is presented in a form that is accessible to a diverse set of skills, roles and responsibilities across the organisation.

Reservoir Modelling and Simulations

Everyone in the Oil & Gas industry understands the huge importance of Reservoir Modelling. It is a crucial operations planning tool that is used by the geoscience community to help Oil & Gas executives figure out just how much money to risk on exploration and production projects, and of course in estimating what the expected returns are from each reservoir.

Reservoir Modelling also places values on physical subsurface characteristics such as water saturation, porosity and permeability, which are important in determining what kind of recovery approach and equipment to deploy, and ultimately where to optimally position wells.

Reservoir Simulation runs enable companies to understand and attempt to predict the behaviour of oil and gas deposits and the subsurface in general as drilling and recovery processes are performed. The accuracy of simulations can be validated by regularly comparing them to actual drilling and production logs, and the level of correctness will have a direct impact on the confidence levels of field personnel. If simulations are way off, then the cost of recovery can rise astronomically, so you need to be able to leverage as much data as possible often, and very quickly. This is another key reason why HPC is critical in the Development and Production stage of the hydrocarbon value chain and why Dell Technologies has focused on developing hyper-converged infrastructure solutions with leading Oil & Gas ISVs that leverage our Dell EMC PowerEdge servers with Intel® Xeon® scalable processors.

Augmented and Virtual Reality for On-demand Information Provisioning, Collaboration and Training

Dell Technologies continues to advance co-development of AR/VR-Ready Solutions that are optimised for consumption alongside mainstream professional Oil & Gas ISV applications. The latest Dell Precision Mobile and Tower Workstations offer the performance, graphics, and memory needed to support immersive use cases that require content creation and advanced commercial visualisation.

Virtual Reality

Of the two visual aid technologies, Virtual Reality is the easiest to apply to the Oil & Gas Industry, particularly for rig platform and refinery workforce training in operating environment familiarisation and Health & Safety procedures. While creating realistic simulated working environments is time consuming, it can be simplified with HPC workstation technology equipped with the correct visual compute graphics accelerators. The final rendering of the virtual world through VR headsets is relatively straight forward, also with correctly configured HPC workstation technology.

The benefits are tremendous, and provide the workforce with many hours of accessible training in a controlled environment without exposing them to unnecessary risk. In essence, VR shrinks the training time-to-proficiency and field-readiness for the workforce by bringing the intended operating theatre virtually to personnel in a safe manner, realistically and at a lower cost than an actual field trip.

Collaboration is the next area where VR delivers tangible value. It enhances information sharing and accelerates more accurate decision-making during asset construction and deployment planning (e.g. for an oil rig, storage facility or refinery). By providing a common 3D medium for otherwise technical architectural drawings, personnel involved in drilling or refinery operations can simultaneously and consistently experience the information. An example where VR collaboration has lowered communication barriers across teams is the visualisation of subsurface data in walk-in 3D virtual models. These environments help increase the understanding and the value of subsurface data exponentially by enabling geoscientists, well planners, drilling engineers and other upstream stakeholders to immerse themselves in the same data. It does so in a way that transforms bits and bytes into an interactive reservoir context.

Augmented Reality

The less compute and graphics intensive of the two technologies, Augmented Reality adds digital information to a real-world view, usually through an eye-piece or glasses. Information can be called up on-demand by voice or through camera-driven automated object recognition technology when workforce personnel are onsite at drilling and recovery field assets, storage tank facilities, pipeline networks and refinery operations.

While the IT resources needed to support AR is relatively smaller than those for VR, AR systems still require the responsiveness of HPC to translate requests to the correct compilation of data to be rendered digitally.
This digital information can be delivered to multiple sensory devices including visual, auditory and haptic (touch-feedback) to:

- Increase operational efficiency during onsite inspections through accelerated asset status determination by only delivering relevant filtered information from a wider data set based on an object of focus
- Improve field workforce safety and efficiency by relaying key procedural information digitally in real-time during equipment installation, maintenance or configuration, particularly for time-critical activity. This enables field engineers to focus on executing manual tasks with increased dexterity by eliminating or significantly reducing the need to hold manuals, other paperwork or devices that are not tools directly related to an engineering task
- Enrich the collaboration process during asset architecture planning by enabling digital information to be overlaid on a real-world view of the proposed development site to preview intending facilities more realistically – e.g. during a visit to an undeveloped field

Asset Performance Monitoring and Predictive Maintenance

Asset Performance Monitoring in Oil & Gas is not confined to drilling and recovery platforms in Upstream Operations but is also relevant to:

- Midstream systems in pipeline assets for storage and hydrocarbon transportation
- Downstream operations for refinery equipment and for retail storage and delivery assets – for example at fuel depots and stations

Understanding how assets are performing in real-time is essential for operations optimisation as well as safety, but it is not enough to truly manage systems effectively. Ideally, preventing a failure is better than reacting to one, and managing costs with forward planning is better than being forced to scale back operations and to artificially limit production. This is where Predictive Analytics and, more particularly, Predictive Maintenance is essential.

For example, compressors are widely used in the Oil & Gas industry to increase the pressure within a reservoir to improve recovery operations and also in the pipeline transportation system for natural gas. Their uninterrupted running for long periods is essential, with a failed compressor costing thousands of dollars per hour in lost production. Since many compressors operate in remote locations, Energy companies that have not embarked on the digital transformation of oil field services are unaware of a failure until an onsite scheduled inspection is carried out – or worse, when a catastrophic equipment failure occurs.

By combining HPC-driven Asset Performance Monitoring and Predictive Maintenance Analytics, data collected from sensors on equipment at the edge can be enriched with manufacturer data as well as operational historian data to identify potential failures before they occur and deploy corrective measures quickly. (See section 'HPC Technical Architecture Considerations and Best Practices – Value of Edge HPC').

Another emerging dimension in asset performance monitoring involves the application of BEM (Buildings Energy Management) found in the Electric Utilities space to onshore or nearshore rigs and platforms (see 'Demand Side Response in Energy HPC Use Cases - Electric Utilities' section in this paper). It relates to the electrification of upstream operations to reduce carbon emissions by replacing equipment powered by diesel or other hydrocarbon fuels with electrical systems by connecting upstream assets to a central electricity grid and onsite renewable energy sources such as solar or wind. For example, according to energy giant Equinor, their Norwegian Johan Sverdrup field in the North Sea, about 140 kilometres west of Stavanger, has CO_2 emissions of just 0.67 kg per barrel thanks to electrification, compared with an average of 9 kg with a standard development employing gas turbines (see Equinor Low Carbon Solutions – Electrification).

Image Analytics for Field Inspection and Infrastructure Failure Detection

The use of drones and fixed video surveillance systems in the external inspection of field assets such as offshore and onshore drill platforms, pipelines, storage tank facilities and refineries has proven to be safer, more responsive and cost-effective than human onsite inspections. Drones are also deployed to inspect assets internally, for example Pipeline Inspection Gauges (PIGs). PIGs use sophisticated instruments and sensors to navigate and collect pipeline data and where appropriate record images and video. Innovations to enable onboard analytics using edge HPC in PIG systems are emerging. Rather than simply collecting massive amounts of pipeline integrity data to be later poured over by humans and analytics, smart PIGs can also be programmed to perform in-voyage anomaly detection such as corrosion, leaks and blockages, and to tag data appropriately. This reduces the time taken to identify and prevent potentially dangerous situations.

Just as important as conventional image analytics for photos and videos is Optical Gas Imaging (OGI) for gas leak detection, and Thermal Imaging to raise the alarm ahead of a potential fire or equipment failure. The rise of image analytics offers a step change in the accuracy and speed with which inspections could be conducted, but it also provides a valuable time-series tool for measuring and cataloguing material degradation.

Combining images and video with Global Positioning System (GPS) and camera angle meta data enables the digital geotagging of each area of interest during a review to increase the accuracy of identifying its precise location. To successfully apply machine learning to train models to detect anomalies and areas of interest across this complex dataset requires HPC. The resulting analytics workload is a more cost effective, practical, reliable and scalable approach to inspection than a manual process.

The nature of images and videos demands an unstructured data management solution in line with the one used in seismic data management. The Dell EMC PowerScale platform is one example from the Dell Technologies data management portfolio that is well equipped to this use case, combining scale-out NAS (Network Attached Storage) and Dell EMC PowerEdge HPC server technology.

Production Optimisation

Unlike the Seismic Processing or Reservoir Modelling use cases, Production Optimisation is less application prescriptive and more data science oriented. Nevertheless, when we look at the multiple data inputs to Production Optimisation (e.g. pipeline and facilities utilisation data, well analysis, logistics data), we can quickly see why HPC is important to its success, particularly when executing multiple production scenarios in order to select the best. In section 'HPC Technical Architecture Considerations and Best Practices – the Value of a Unified HPC Architecture', we present a scalable HPC platform that supports the characteristics of Production Optimisation.

One of the key factors in Production Optimisation is the collection of data sets from various dimensions across operations that need to be time-series aligned. In other words, for meaningful HPC-driven analytics to be performed, data streaming from field or refinery systems related to the volume of hydrocarbons being recovered or processed daily must also line up with workforce deployment figures for the same period and so on. Therefore, the correct cataloguing of data is paramount in order for related data sets to be promptly retrieved with confidence and analytics performed, insights derived and actions taken to maximise production.

For example, in Upstream operations, Production Optimisation analytics can help companies figure out how to triple the number of wells in a field over the next 10 years without also needing to triple the size of the workforce. In Downstream operations, the use case assists with capacity planning within a refinery to ensure that forecasted raw hydrocarbons can be converted to commodities economically within stringent environmental regulations and in line with planned maintenance schedules for various sections of the plant.

Undoubtedly, Production Optimisation outputs have implications for Predictive Maintenance scenarios as the number of assets needed to achieve production goals will have a bearing on the extent of projected equipment wear.

Logistics Optimisation

Effective logistics management can make the difference between:

- a minor repair or an extended period of refinery equipment downtime
- a drilling project starting on time or a costly delay because of a lack of skilled workforce
- a surplus of fuel or regional economic downturn due to a supply chain anomaly

Generally speaking, the process of optimising logistics is well understood, with no shortage of enterprise-grade applications available either as an on-premises deployment or off-premised cloud-based. However, challenges still remain when the pressure to reduce operational costs leads to increasingly fragile just-in-time parts delivery, equipment maintenance and personnel scheduling systems. Supply chains by definition require the collaboration of several companies with at least as many separate tracking and alert systems, so the accurate and timely exchange of information is critical. The more data lag there is in logistics operations, the more tolerances to manage delays there needs to be, and this has a direct upward impact on operational costs.

Automation and digitalisation inevitably play a significant role in streamlining logistics systems, but automation usually introduces more equipment into the supply chain, which increases the load on predictive maintenance or in some cases predictive replacement activities.

The bottom line is that logistics optimisation requires data to be rapidly and accurately collected, validated, processed, shared and processed again as it moves through supply chains, which is ideal for HPC infrastructure. If logistics systems fail, the ripple effect will be felt all the way through to production levels and subsequently to Oil & Gas company revenues and potentially to global market prices.

Blockchain Energy Trade

Trading in raw and refined products requires manual multi-step processes where information is repeatedly entered into a variety of systems along the trading chain. In order to preserve the integrity of transactions, data reconciliation processes are inserted into each step, which increases the time it takes to complete a transaction.

With the distributed ledger approach of blockchain, the manual re-entry of data across myriad systems together with tedious reconciliation practices can be eliminated by making the same pre-validated information available to all transaction parties simultaneously. Oil & Gas companies could execute trades with greater price and volume accuracy, reduce security risks associated with storing multiple copies of data in several systems, and accelerate invoicing and settlement processes.

In fact, by adding IIOT technology practices to the supply chain, sensor technology in refinery equipment, pipelines, and other fulfilment assets can track product output and facilitate accurate real-time invoicing of customers not dissimilar to everyday experiences at the petrol pump or electric vehicle charge points. Digitalised inventory management, contracting and invoicing processes require fewer human resources to operate, are quicker than traditional approaches and are less open to fraudulent activity.

Blockchain technology can be driven by HPC to deliver the speed of response, trade transaction volume throughput and consistent execution of compliance-validating analytics required for successful global trading in the Oil & Gas industry.

Customer Behaviour Analytics

The further left we go across the hydrocarbon value chain, the less data and computer intensive the customer analytics requirements are. It is simply a matter of numbers. As we move to the right side of the value chain, the number of sellable products and customers increases significantly, and if an Oil & Gas company has retail operations, then customer analytics requirements are every bit as sophisticated as those employed by supermarket retailers. Successful customer loyalty programmes increase brand efficacy and by definition keep customer retention scores high, although loyalty can take a backseat to pricing during extended fuel crises.

The fuel station forecourt continues to expand beyond simply offering fuel, evolving into customer experience centres where non-fuel convenience products and services thrive, particularly at stations serving long distance travellers, and those close to commuter start and end points.

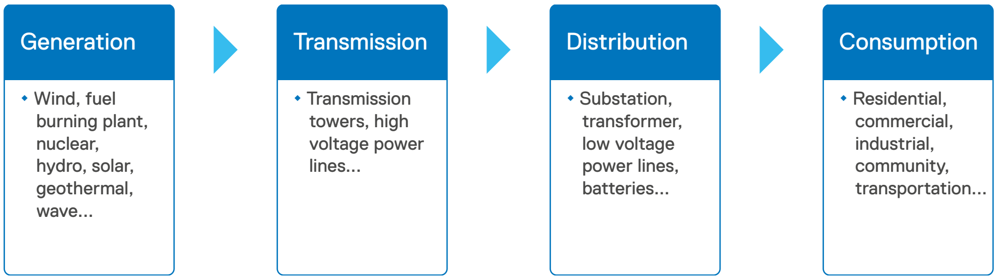
Fuel businesses that diversify to offer charging stations for Electric Vehicles (EVs) are presented with the gift of time, since charging an EV takes on average significantly longer than a pit stop for hydrocarbon-based fuel. This window offers the opportunity to turn that wait time into revenue, although the extent to which EV users will utilise mass charging stations the way drivers of combustion engine vehicles do is unclear. EV users have options other drivers don’t. They can charge their vehicles at home, in car parks, and even at work, so are not 100% reliant on centralised energy services.

The net result of the complex mix of fossil fuels and electricity energy consumption is that customer segmentation, valuation, retention, cross-sell and upsell analytics is vitally important to Oil & Gas companies with significant retail facilities, and HPC technology is key to continually and successfully mining value from customer transactions in a timely manner. Understanding and predicting consumption behaviour in the context of the wider energy market better influences production optimisation activities further up the value chain. Even a company with an Energy retail presence but no upstream Oil & Gas operations can monetise customer analytics outcomes by offering the insight to those Energy companies that do.

Many Oil & Gas companies rely on enterprise software for managing business operations and customer relationships from industry leaders like SAP. Dell Technologies has developed SAP-certified analytics platforms that utilise data centre modernisation technology, including Dell EMC PowerEdge HPC servers to accelerate the implementation and execution of the high performance analytics appliance SAP HANA. (See how Pakistan Petroleum Limited (PPL) delivers key business reports three to four times faster with SAP HANA running in a Dell Technologies private cloud).

Energy Use Case Examples for HPC – Electric Utilities

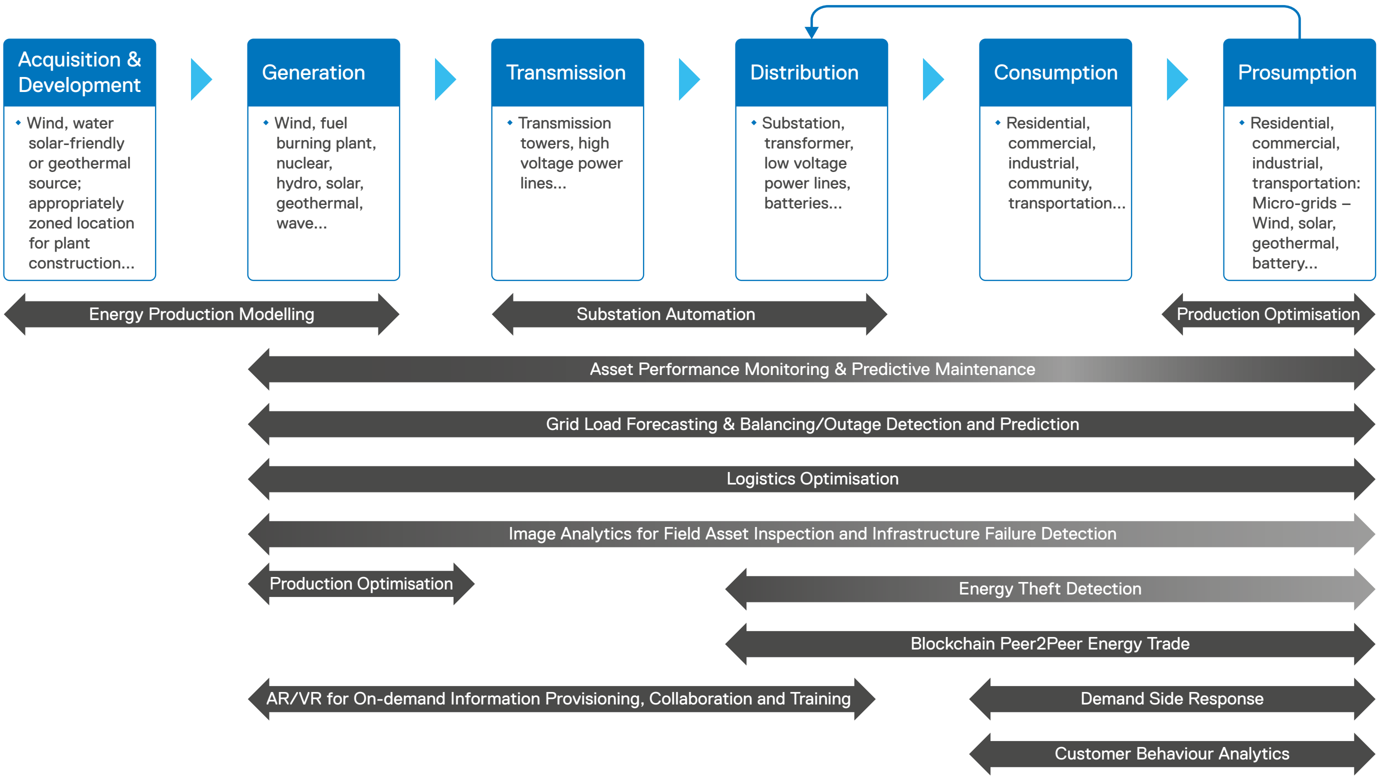
To determine where HPC can deliver overall business efficiencies within Electric Utilities, we should examine the industry's value chain, which is commonly described in four stages – Generation, Transmission, Distribution and Consumption.



Simplified Electricity Value Chain

Today as the number of electricity sources increases and the way consumers are reimagining energy as a commodity, a more contemporary value chain is required, consisting of six stages:

1. Acquisition and Development – Selecting viable locations and constructing electricity generating facilities
2. Generation – Producing electricity from an energy source
3. Transmission – Transferring high voltage electricity to distribution networks
4. Distribution – Delivering electricity to consumers
5. Consumption – Using electricity
6. Prosumption – Producing electricity as a consumer, and selling energy into distribution networks



Example HPC Use Cases for Electric Utilities Industry

Energy Production Modelling & Production Optimisation

Accelerated by the growth of the renewable energy market, Acquisition and Development has emerged as an important stage in the electricity value chain. Finding appropriate locations to construct generators powered by wind, water, sun or even nuclear reactors requires far more science than is required to plan a generator powered by coal or natural gas.

For example, when assessing a site for a potential windfarm, parameters such as proximity to electrical grid distribution networks, distance from residential and other sensitive areas such as airports, historical and protected environmental locations need to be carefully considered. Pinpointing the precise location and configuration of windfarms increases by another magnitude of complexity as additional more granular factors must be considered, such as the annual mean wind speed at the corridor height for proposed wind turbines, the amount of noise generated relative to background decibel levels at various times throughout a day, and the effect of electromagnetic interference from the proposed windfarm on wireless communications such as TV and mobile phone networks. These parameters are blended with data about potential wind turbine designs, various configurations for the turbine placements and the geological suitability of the land for development to determine viable scenarios that satisfy acceptable economic thresholds.

This Energy Production Modelling requires careful execution of analytics and simulation runs, which is precisely what HPC is designed to facilitate. The modelling continues to be necessary even after generator facilities are up and running, transforming into a Production Optimisation workstream. In this use case, the inputs include real-time data points about the electricity generated by each producing asset in order to continuously optimise the economic viability of the site. (See section 'Value of Edge HPC – Real-time HPC Analytics at the Edge').

Asset Performance Monitoring and Predictive Maintenance

Apart from passive energy sources such as solar, generating electricity requires the movement of parts in a motor or turbine, which represents a wear-and-tear factor that cannot be ignored. Asset Performance Monitoring coupled with Predictive Maintenance Analytics is a key use case for HPC, where data collected from sensors on equipment can be enriched with manufacturer data as well as operational historian data for the generation site to reduce systems downtime due to unplanned maintenance events or equipment failures.

Asset Performance Monitoring and Predictive Maintenance is not confined to generator assets but also to equipment across the entire electricity value chain, including transformers, circuit breakers and substations.
The impact of effective Predictive Maintenance not only reduces operational costs, but also delivers compliance benefits where fines can be avoided for breach of agreed electricity supply service levels. There is also reputational damage when reliability of service comes into question, or if equipment failure results in harm to human health, safety or the environment. The end result is likely to be a loss of customer trust, and financial market confidence if the operating company is public. Predictive Maintenance is an effective risk mitigation tool against these potential consequences.

Effective preparation for Predictive Maintenance needs to be implemented as a combination of reliable edge data collection and aggregation usually under rugged conditions, and centralised data management involving data cleansing and data enrichment workflows. HPC-driven analytics can then be deployed for model creation and execution. (See section 'HPC Technical Architecture Considerations and Best Practices – Value of Edge HPC').

Augmented and Virtual Reality for On-demand Information Provisioning, Collaboration and Training

Dell Technologies continues to optimise the Dell Precision Mobile and Tower Workstation portfolios to offer the performance, graphics, and memory needed to consolidate volumes of technical information into a contextual experience for Electric Utilities immersive use cases.

Virtual Reality

Of the two visual aid technologies, Virtual Reality is the easiest to apply to the Electric Utilities Industry, particularly for workforce training in field asset familiarisation and Health & Safety procedures. While the process for creating realistic simulated working environments is time consuming, it can be simplified with HPC workstation technology equipped with the correct visual compute graphics accelerators. The final rendering of the virtual world through VR headsets is relatively straight forward, also with correctly configured HPC workstation technology. The benefits are tremendous, and provide the workforce with many hours of accessible training in a controlled risk-free environment. In essence, VR shrinks the training time-to-proficiency and field-readiness for the workforce by bringing the intended operating theatre virtually to personnel in a realistic and safe manner, and at a lower cost than an actual field trip.

Collaboration is the next area where VR delivers tangible value. It enhances information sharing and accelerates more accurate decision-making during asset construction and deployment planning (e.g. for generation plant, substation or transmission network). By providing a common 3D medium for otherwise technical data, personnel involved in electricity generation, transmission and distribution operations can simultaneously and consistently experience the information and interpret it in line with their skillset. An example where VR collaboration has lowered communication barriers across teams is the visualisation of windfarm construction 'walk-in' 3D virtual models. These environments bring together data about the annual mean wind speed at the corridor height for proposed wind turbines, the amount of noise generated relative to background decibel levels, and the effect of electromagnetic interference to present it in a form that executives, land developers, engineers, and community representatives can simultaneously understand.

Augmented Reality

The less compute and graphics intensive of the two technologies, Augmented Reality adds digital information to a real-world view, usually through an eye-piece or glasses. Information can be called up on-demand by voice or through camera-driven automated object recognition technology when workforce personnel are onsite in an Electric Utility operating environment.

The scope for AR in Electric Utilities is broad, ranging from the passive, where information rendered is largely academic (e.g. describing a piece of equipment, or relaying maintenance instructions), to the dynamic (e.g. pointing an AR device at a wind turbine and visualising real-time power output figures).

While the IT resources needed to support AR is relatively smaller than those for VR, AR systems still require the responsiveness of HPC to translate requests to the correct compilation of data to be rendered digitally. This digital information can be delivered to multiple sensory devices including visual, auditory and haptic (touch-feedback) to:

- Increase operational efficiency during onsite inspections through accelerated asset status determination by only delivering relevant filtered information from a wider data set based on an object of focus
- Improve field workforce safety and efficiency by relaying key procedural information digitally in real-time during equipment installation, maintenance or configuration, particularly for time-critical activity. This enables field engineers to focus on executing manual tasks with increased dexterity by eliminating or significantly reducing the need to hold manuals, other paperwork or devices that are not tools directly related to an engineering task
- Enrich the collaboration process during asset architecture planning by enabling digital information to be overlaid on a real-world view of the proposed development site to preview intending facilities more realistically – e.g. during a visit to an undeveloped field.

Image Analytics for Field Asset Inspection and Infrastructure Failure Detection

High voltage electricity transmission is a less mechanical process than electricity generation. As a result, any Predictive Maintenance workflows are likely to be less complex than those focused on equipment with moving parts.

However, image analytics is being increasingly used to digitally inspect power transmission lines and other utility field assets across the electricity value chain, with drones emerging as the most efficient vehicle for capturing photos and video footage. When combined with Global Positioning System (GPS) and camera angle meta data, the images can be geotagged to increase the accuracy of identifying the precise location of each area of interest during a review.

As manual inspections of images and indeed actual physical assets is time consuming and prone to error, using machine learning to train models to detect anomalies and areas of interest is a more practical, reliable and scalable approach to inspection, not to mention the significant reduction in cost. HPC is invaluable to both the model training and execution aspects of image analytics, given the amount of unstructured data to be inspected.

In addition to examining actual electricity assets in the field, the trees that grow around these assets is of particular concern to the extent that an entire sub-industry of Electric Utilities Vegetation Management (UVM) has sprung up. By keeping branches away from powerlines, blackouts during both normal conditions and environmental disasters such as extreme weather and geological anomalies can be limited. Being a step ahead of the vegetation drastically cuts the window of opportunity for tree-falling incidents and the associated losses electric utilities can incur from them. UVM is not the same as common gardening at an industrial scale, so a simple process of regular pruning is not adequate. Trimming trees stimulates them to come back stronger and thicker, but crews can take advantage of this during vegetation management by pointing the new growth away from powerlines.

Done well, electricity UVM is scientific, beginning with a program cycle of thorough pre-inspection of vegetation around field assets. Experts collect data about vegetation species, locations and growth rates to create detailed work plans to optimise the vegetation management process. Using drones is by far the most efficient way of gathering much of this data using video and photographs and subsequent inspections can be carried out more frequently than human field crews ever could.

In summary, the nature of images and videos requires an unstructured data management and HPC-driven analytics solution. The Dell EMC PowerScale platform is one example from the Dell Technologies data management portfolio that is well equipped to this use case, combining scale-out NAS (Network Attached Storage) and Dell EMC PowerEdge HPC server technology.

Substation Automation

The Substations that provide the interface between high voltage transmission networks and Distribution power lines need to function within an increasingly complex grid, driven in part by the rise in the number of energy sources, primarily from the growth in the renewable energy subsector. Another important contributor is the need for substations to perform operations with a lower carbon footprint. As a result, the hardwired circuitry required to perform voltage step-up and step-down functions, as well as controlling protective devices such as circuit breakers and industrial grade fuses, needs to be replaced with a more versatile system.

By virtualising the physical controller mechanisms in substations into a software defined platform, the ability to respond to the increasing grid complexity is vastly improved, and enables sophisticated HPC-driven automated decision systems to be deployed and upgraded remotely. This innovation facilitates a safer and more agile substation management process than the traditional architecture would allow.

Grid Load Forecasting and Balancing/Outage Detection and Prediction

Grid Load Forecasting and Balancing (matching energy supply to expected demand) carried out by a Transmission System Operator (TSO) has traditionally been a relatively simple operation when electricity generation was driven by fossil fuels. Short-term deviations in expected demand are usually catered for by ramping gas-fired powered plants up or down.

However, as we globally shift away from fossil fuelled electricity generation and rely more on renewable energy systems (wind, solar, hydro, geothermal, wave), grid load balancing becomes significantly more complex as electricity production is generally less predictable from these sources (intermittent wind, cloud cover, tidal fluctuations). As a result, the complete removal of fossil fuelled electricity generation is not feasible until a larger quantity of highly responsive renewable energy systems that can also be ramped up or down are implemented. Industrial scale battery technology is one solution to this challenge, where excess energy can be stored when supply is in excess, and then released when demand peaks significantly. Digital innovation in electricity grids is necessary to enable supply and demand data points to be captured, analysed and modelled using HPC in order to help TSOs respond with greater agility. The solution avoids outages and facilitates early remedial action against predicted failures.

There are also other innovative industrial approaches to tackling excess energy, such as Pumped Hydroelectric Energy Storage (PHES). This method stores energy in the form of the gravitational potential energy of water lifted to a higher elevation reservoir from a lower elevation using pumps typically driven by low-cost surplus off-peak electricity. Consequentially, when electricity demand is high, the stored water is released through turbines to generate electricity. However, the economics of this approach is subjective. PHES activity could make such a hydroelectric plant a net consumer of electricity, but if more generated electricity could be sold during peak demand rates, then a plant could be a net revenue and energy producer.

Load Forecasting and Balancing can also have significant financial implications for businesses responsible for managing an electrical grid. For example, producers of renewal energy like wind can be paid to temporarily halt electricity production during periods of low demand. However, by combining energy production with energy storage practices, the need for financial pay-outs as a major lever for managing over-capacity can be reduced.

The complete implementation of Grid Load Forecasting and Balancing requires the coordination of HPC at the edge with HPC at the core data centre, both of which are covered in the section 'HPC Technical Architecture Considerations and Best Practices'.

Logistics Optimisation

The process of optimising logistics is well understood, with many organisations offering enterprise-grade applications available either as an on-premises deployment or off-premised cloud-based. However, challenges still remain when the pressure to reduce operational costs leads to increasingly fragile just-in-time parts delivery, equipment maintenance and personnel scheduling systems. Supply chains by definition require the collaboration of several companies with at least as many separate tracking and alert systems, so the accurate and timely exchange of information is critical. The more data lag there is in logistics operations, the more tolerances to manage delays there needs to be, and this has a direct upward impact on operational costs.

Effective logistics management can make the difference between:

- a minor repair or an extended regional outage
- a renewable energy project starting on time or a costly delay due to a shortage of skills or equipment
- a highly efficient smart grid or insufficient network capacity for large scale smart meter deployment

Compared to the Oil & Gas Industry, the Electric Utilities industry faces a bigger overall logistics challenge. Solar, wind, hydro, geothermal, and wave plants of various sizes are being built at pace, but carrying out demand forecasting, fulfilling construction and adjusting grid load balancing models is a highly dynamic situation. In this scenario, logistics is more than moving personnel and equipment around, and requires complex routing analytics to minimise the chances of equally damaging electricity under or over capacity scenarios.

The bottom line is that logistics optimisation requires data to be rapidly and accurately collected, validated, processed, shared and processed again as it moves through supply chains and electricity distribution networks, which is ideal for HPC infrastructure.

Demand Side Response

The Consumption and Prosumption stages of the electricity value chain represents a growth opportunity for Electric Utilities driven by two key factors relevant to consumers across all categories (residential, commercial, industrial, transport):

1. The need for consumers to reduce their carbon footprint by managing energy usage more effectively
2. The distributed nature of renewable energy technology that enables consumers to produce meaningful amounts of energy that could be sold to the grid distribution system – prosumption activity

The use of smart meter technology is only the tip of the digital revolution for the energy consumer. Home and Buildings Energy Management Systems offer a granular method to not only understand consumption patterns and overlay time-series charge rates, but to also automate the process of optimising when electrical devices use energy. As mentioned in the section 'The Digitalisation of the Energy Eco-system', Electric Utilities are already working with commercial and industrial consumers with Demand Side Response (DSR) solutions that require the digitalisation of electrical equipment with sensors, and that utilise data centre practices to collect and analyse energy usage information. For example, DSR combined with BEMS (Buildings Energy Management Systems) can also be used by manufacturing enterprises to increase profit margins by reducing production costs and streamlining fulfilment logistics – to redefine production line practices to group long running equipment tasks together where possible and executing them in the periods of the work day when energy rates are known to be low.

Residential customers also benefit from the DSR innovation. HEMS (Home Energy Management Systems) present consumers with the opportunity to manage a diverse set of systems in their homes including lighting, electronics, smart appliances and thermostats/HVAC (Heating, ventilation and air conditioning). The potential energy savings from HEMS is significant. Once this technology becomes pervasive, we can expect to see community and regional carbon reduction regulations being introduced to residential customers in a way similar to those currently applied to commercial and industrial businesses. In fact, we already see similar regulations rolled out in transportation, where fuel efficiency is rewarded with tax breaks and exemptions, and more polluting vehicles are punished with charges, fines and taxes.

HPC ensures that both BEMS and HEMS are highly responsive systems that employ AI analytical workloads to deliver a dynamic service, with BEMS requiring the larger HPC footprint. However, HPC for HEMS should not be underestimated, as the complexity of analytics increases when prosumption is added to the energy efficiency workloads. In fact, both BEMS and HEMS deployments become more analytics intensive if energy generated from on-premises renewable sources such as solar, wind, thermal, or from near-line local community micro-grids are included to optimise energy usage. Not only will the BEMS or HEMS systems maximise electricity rates from mainstream electrical grids, but they can also eliminate the mainstream grid altogether for significant periods of time by leveraging the local energy source.

Customer Behaviour Analytics

Electric Utilities have long engaged in Customer Behaviour Analytics by segmenting consumers using demographics, rate sensitivity and macro-consumption data (weekly, monthly, quarterly). As Smart Grid technology today enables much more granular customer data to be collected – for example micro-consumption data from smart meters – Electric Utilities are in a stronger position to better understand their customers and to create new products and services to increase both customer satisfaction ratings and revenues.

HPC not only speeds up traditional analytical workloads such as customer segmentation and customer valuation analytics, but it can also be deployed to execute AI workloads to unlock answers to questions companies do not even know to ask yet. More immediately, however, Customer Behaviour Analytics complements the Demand Side Response use case beautifully to help Electric Utilities offer a more holistic customer experience that is increasingly lifestyle-oriented for residential customers and business process-focused for commercial and industrial ones.

Many Electric Utility companies rely on enterprise software for managing business operations and customer relationships from industry leaders like SAP. Dell Technologies has developed SAP-certified analytics platforms that utilise data centre modernisation technology, including Dell EMC PowerEdge HPC servers to accelerate the implementation and execution of the high performance analytics appliance SAP HANA.

Energy Theft Detection

During electricity transmission and distribution, energy loss is experienced for 'technical' and 'non-technical' reasons. Technical Losses (TLs) are caused by internal system interactions as electricity passes through networks, with energy being dissipated from conductors, transformers, substation equipment and power lines. Non-Technical

Losses (NTLs) on the other hand are primarily caused by electricity theft by direct line tapping, traditional mechanical meter breaking or tampering, and hacking Advanced Metering Infrastructure (AMI). This fraudulent behaviour costs utility companies billions of dollars globally. Additionally, these acts, if allowed to propagate, may put public safety and the environment at risk, ranging from fatal electrocutions during improper line tapping, to fires where excess loading causes unprotected electrical wiring to fail.

For these reasons, Electric Utilities exposed to electricity theft attempt to deploy advanced analytics that leverage linear regression algorithms, deep learning neural networks and other advanced analytics to detect fraud as quickly and as accurately as possible, an ideal use case for HPC.

Blockchain Peer-to-Peer Energy Trade

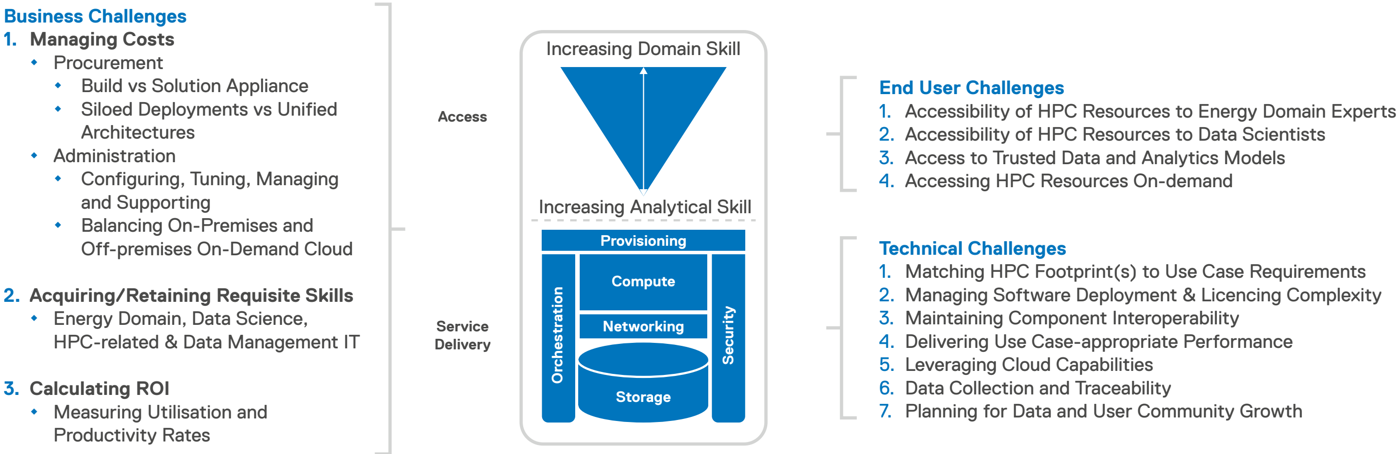
As the prosumption economy grows and transforms the energy industry into a mature Distributed Energy Resources (DER) model, direct transactions between Prosumers and Consumers (also known as Peer-to-Peer (P2P) energy trading transactions) will also increase. Blockchain technology promises to simplify and scale the complex process of managing the trades with the degree of security, accuracy and trust needed to legitimise this new market opportunity.

The position of traditional Electric Utilities companies in the P2P Energy Trading model is uncertain, given one of the primary objectives of the model is to eliminate the energy companies from the P2P transaction process. However, it is generally agreed that one or more Energy Trading platforms driven by blockchain technology will be required, and this is where new businesses, including energy companies (subject to regional monopolies law), may be able to participate.

Nevertheless, blockchain technology requires HPC to perform the transaction validation processes that underpins it.

Deploying HPC for Energy – Challenges and Solutions

While HPC is a necessary ingredient for successful analytics environments across a variety of Energy use cases, implementing it strategically is less straightforward. Challenges must be met, and they typically fall into three broad categories:



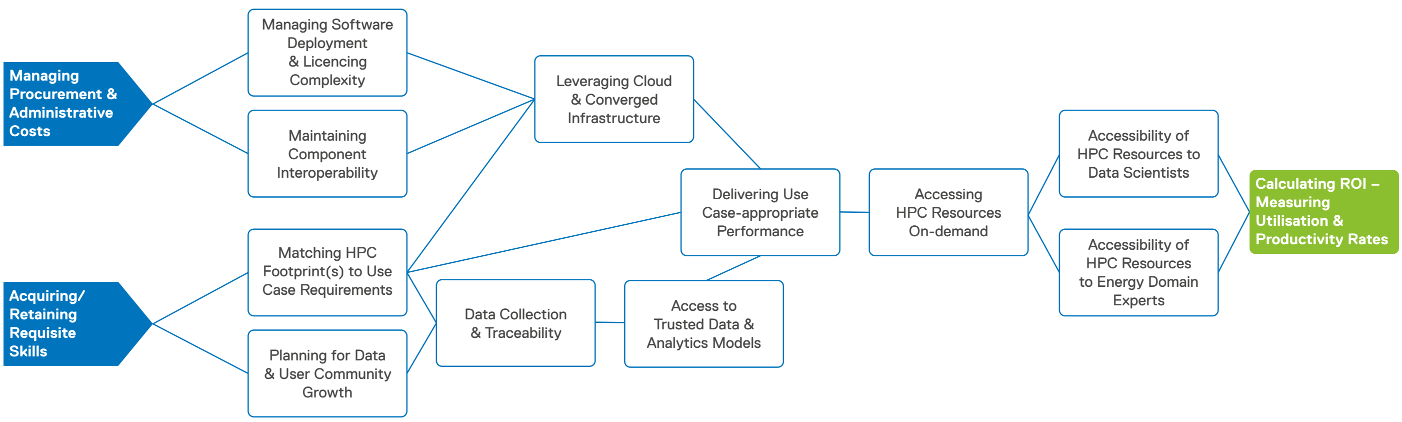
Challenges in deploying HPC

1. **Business Challenges**, centred around managing procurement and ongoing administrative costs, finding and retaining the correct talent that can translate Energy business needs and vision into viable analytics use cases, and of course calculating the return on investment (ROI) of deploying HPC in order to justify and improve its implementation.

2. **End User Challenges**, focused on facilitating access to HPC resources by Energy domain experts and data scientists. It is worth splitting the user community into these two groups because each tends to approach analytics with different expectations. Energy domain experts typically require an off-the-shelf flexible user interface that hides the underlying technical complexity of data storage and computing infrastructure, whereas data scientists usually require tools that enable them to manipulate raw data and to create algorithms and models in a more technical environment. Where they are undoubtedly unified though is the desire for access to data and analytics models they can trust, and the ability to call up HPC resources on-demand rather than primarily on a scheduled basis over which they have little influence.

3. **Technical Challenges**, which ultimately stem from the need to match the spectrum of HPC form factors to use case requirements, managing the complexity of software licences and the interoperability of IT components, leveraging cloud and converged infrastructure capabilities, enabling consistent and traceable data collection from a multitude of data sources and planning for operational growth which may result in even more data being generated for a wider community of analytics stakeholders.

The first step to defining a winning HPC strategy is to prepare for and to address the challenges in a way that leverages the inter-relationships between them to produce cascading value. In other words, rather than listing the challenges and attempting to address each independently, start with the ones where applying focused thought and solutions naturally cause a ripple effect that eliminates or significantly diminishes other obstacles – similar to the Bowling Pin Strategy.



Taking Control of HPC Challenges

The holistic approach avoids constraining HPC environments by cementing unnecessary compromises into technical architectures. To the left of the diagram above, we have two key macro-challenges that are ever present throughout the life of any HPC environment, and at the far right is the 'litmus test' for any environments deployed. The pieces between these three challenges determine the ongoing success of HPC strategies.

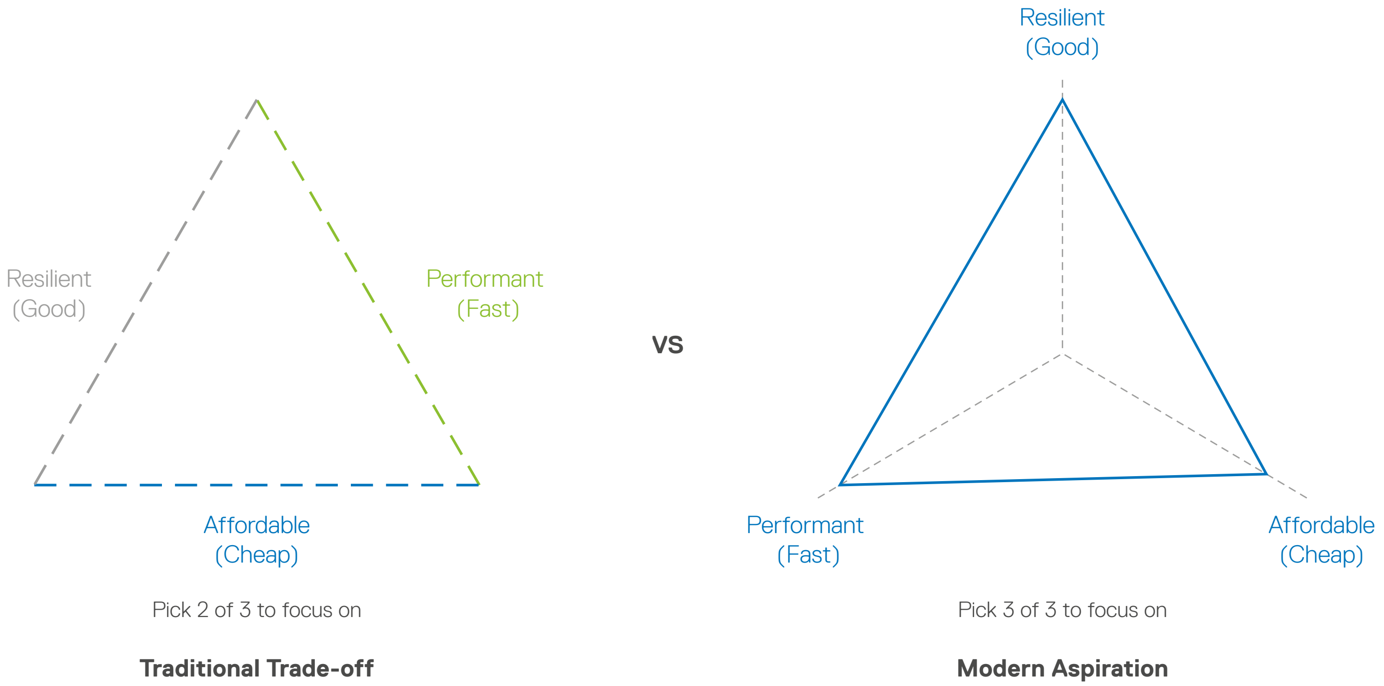
How it works

For example, in order to deliver HPC resources to Energy domain experts and data scientists for maximum productivity, the users need to be able to access the resources on-demand. The potential value in data tends to decay over time, so the longer it takes to complete an analytics project on data collected across the organisation, the less likely significant actionable insight will be uncovered. But in order to confidently offer an on-demand HPC service, the underlying infrastructure deployment or deployments must be capable of delivering use case-appropriate performance, which is why it is essential to keep Energy Domain Experts involved throughout HPC strategy development. Starting with a technology-biased discussion runs the risk of producing an environment that is conducive to only certain types of HPC workloads, which in turn negatively impacts an Energy company's chances of optimising and innovating its business.

Delivering appropriate performance for a range of use-cases requires a degree of flexibility only possible by considering:

- Cloud Computing Models to enable scalability
- Converged and Hyper-Converged Infrastructure to simplify IT resource interoperability
- Virtualisation to manage the provisioning of these combined resources effectively

With these three elements, we can refuse to give in to the widely used 'triangle model' project management principle that states it is impossible to define an initiative that is simultaneously Good (Resilient), Fast (Performant) and Cheap (Affordable), and that the hard choice of deciding which two of the three to focus on is the shrewd approach. In reality, we do not need to only choose two out of three for HPC, but rather degrees of all three, where the model is better expressed as a spider chart rather than a triangle or a Venn Diagram.



HPC Strategies

With Dell Technologies HPC solutions powered by 2nd Generation Intel® Xeon® Scalable Processors, Energy companies are able to implement an overall Modern Aspiration strategy to achieve Resilient, Performant and Affordable HPC with solutions that blend cloud computing, converged and hyper-converged infrastructure, and virtualisation. We will discuss this further in the section 'HPC Technical Architecture Considerations and Best Practices'.

In parallel, understanding the data sources across Energy operations that will feed analytical workloads is vital. Without appropriate meta-data tagging to enable data to be selected for model development and other analytics, it will be impossible to place any results into a meaningful context for the business to interpret.

This exercise has a profound impact on defining the degree of distributed HPC configurations that will be necessary. While it is unlikely that HPC will be deployed at the edge for model creation workloads, it is highly likely that model execution workloads at the edge requiring an HPC footprint will be necessary to sustain response agility levels – for example to drive electricity load balancing systems in grid management processes and incident prediction systems in Oil & Gas production operations.

Finally, it is worth reiterating that this approach is not advocating a 'one size fits all' solution to every HPC Energy use case, bearing in mind the HPC footprint spectrum outlined in the Section 'Modern HPC is more than just Supercomputing Clusters'. However, the underlying ethos of the approach is applicable throughout, and will naturally constrain the number of siloed HPC environments deployed in an organisation, reducing procurement and administrative costs while improving the overall business case and ROI for the HPC strategy. When making the business case for HPC, ensure that the accountability for the delivery and receiving of the benefits are not simply recorded by department or division designations, but by the names of the individual people at both ends of the implementation. This facilitates an invaluable level of cadence when tracking material HPC gains on an ongoing basis.

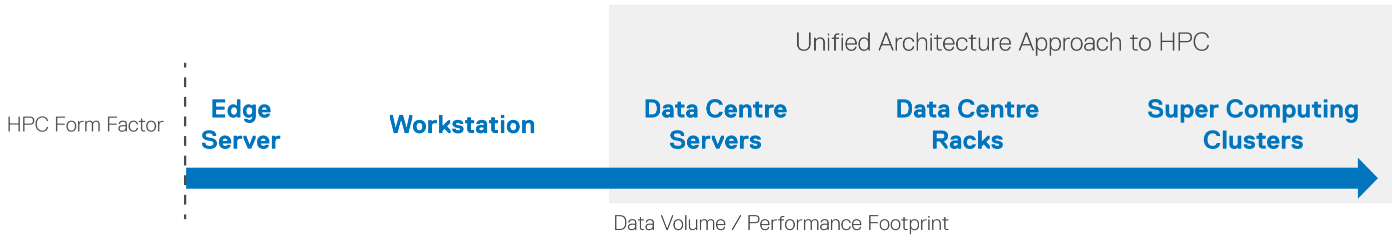
HPC Technical Architecture Considerations and Best Practices

The Value of a Unified HPC Architecture

In the 'Modern HPC is more than just Super Computing Clusters' section, the HPC Form Factor spectrum and Form Factor Matrix both remind us that HPC has value for single user and small data footprint environments as well as for multi-user complex data lake-driven ones.

This diversity of HPC implementations is reflected in the sections 'Energy Use Case Examples for HPC – Oil & Gas' and 'Energy Use Case Examples for HPC – Utilities'. A key observation that Dell Technologies and Intel® have made is that as the number of use cases in an industry's value chain increases, so do the interdependencies between them. Take for instance Reservoir Characterisation & Modelling in Oil & Gas. The output from this use case has input benefits to the Asset Performance Monitoring and Predictive Maintenance use cases for oil field operations, which in turn generate value that can be absorbed by the Production Optimisation use case.

Recognising these interdependencies will have a profound positive effect on when use case workloads are executed. It also provides the added bonus opportunity to unify business and IT stakeholders to create a successful overall HPC strategy, and significantly reduces the chances of experiencing the financial and administrative overheads that would have undoubtedly resulted from the proliferation of siloed HPC deployments. With years of experience in the Energy industry, Dell Technologies has found that it is both technically and economically possible to define a Unified Architecture that supports the part of the HPC spectrum to the right of the Workstation footprint and that can serve all three HPC deployment Zones discussed in the section 'Organising Energy Businesses to Maximise Success with HPC'. In practice, it is likely to be predominantly used for Zones 2, 3 and 4 deployments.



Where a Unified Architecture Approach to HPC fits

One unified or converged architecture frequently makes the most business sense. The ability to run multiple Energy workloads on a single infrastructure lowers the cost for hardware, software, and maintenance, and it provides additional savings by reducing power and cooling costs, ultimately shrinking the overall IT carbon footprint.

Dell Technologies has conducted a TCO analysis to measure the cost of three HPC environments compared to one environment. The analysis considers the following costs:

- Purchase price of hardware, software, service, and support
- Management, power and cooling costs
- Staff cost

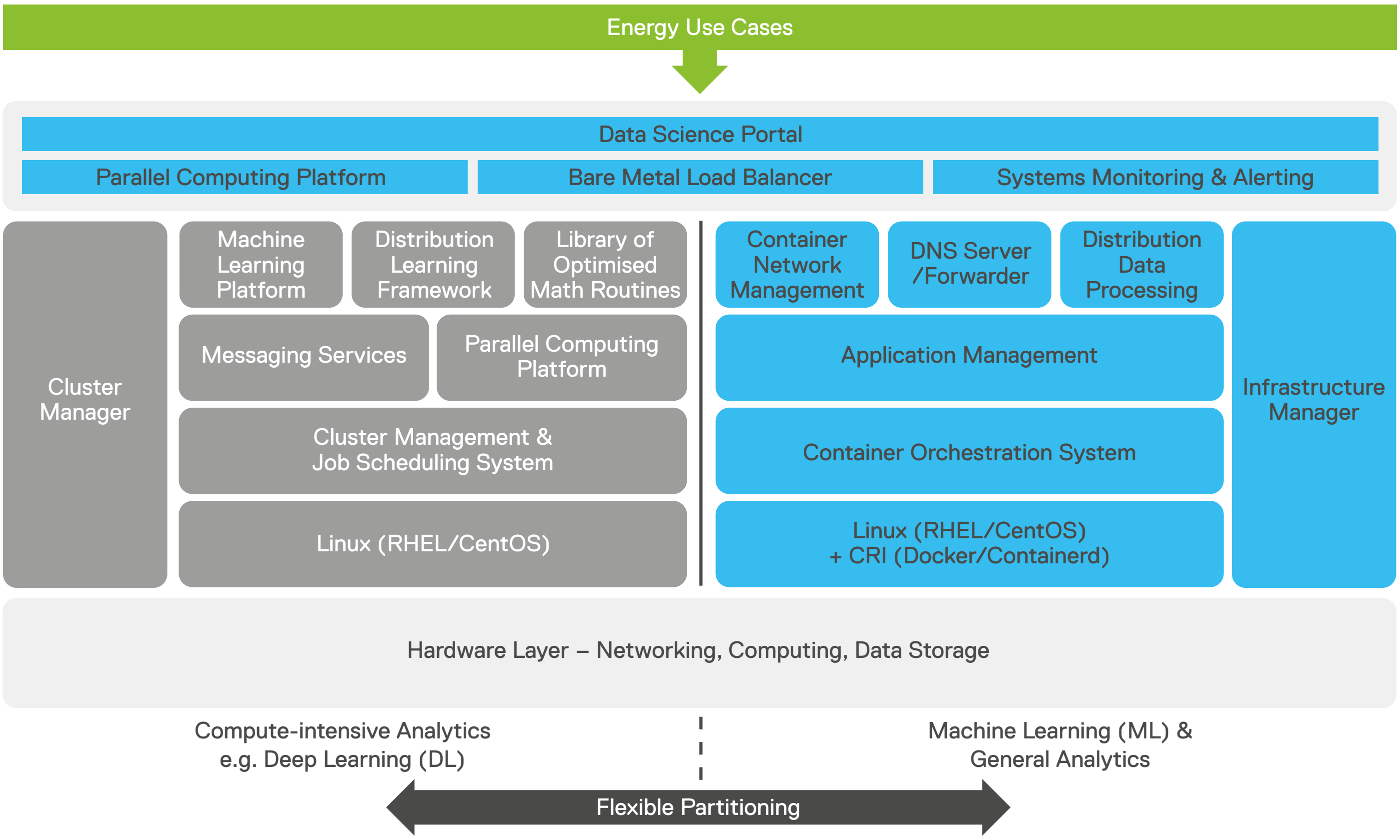
The analysis revealed that over a three-year period, **implementing one HPC environment cost 30% less to purchase, required 40% fewer people to manage, and cost 30% less to run** (including staff, management, power and cooling). Even more telling was that **the three combined environments saw a cost of $480K more per workload, and used $302K more power than the unified environment** (see Dell Technologies 'TCO Analysis — HPC Ready Architecture for AI and Data Analytics' whitepaper).

While it is likely that some specialised Super Computing Clusters would require bespoke designs, our findings are that the majority of analytics and AI workloads can be serviced effectively with a unified architecture. This does not mean that there will only be one HPC deployment with a unified architecture across the entire Energy organisation. However, where there are practical reasons for having multiple deployments, having them designed based on a common architecture enables all to be managed efficiently by a small number of IT resources, and the end user experience across the organisation is consistent and easily optimised.

Dual Brain HPC

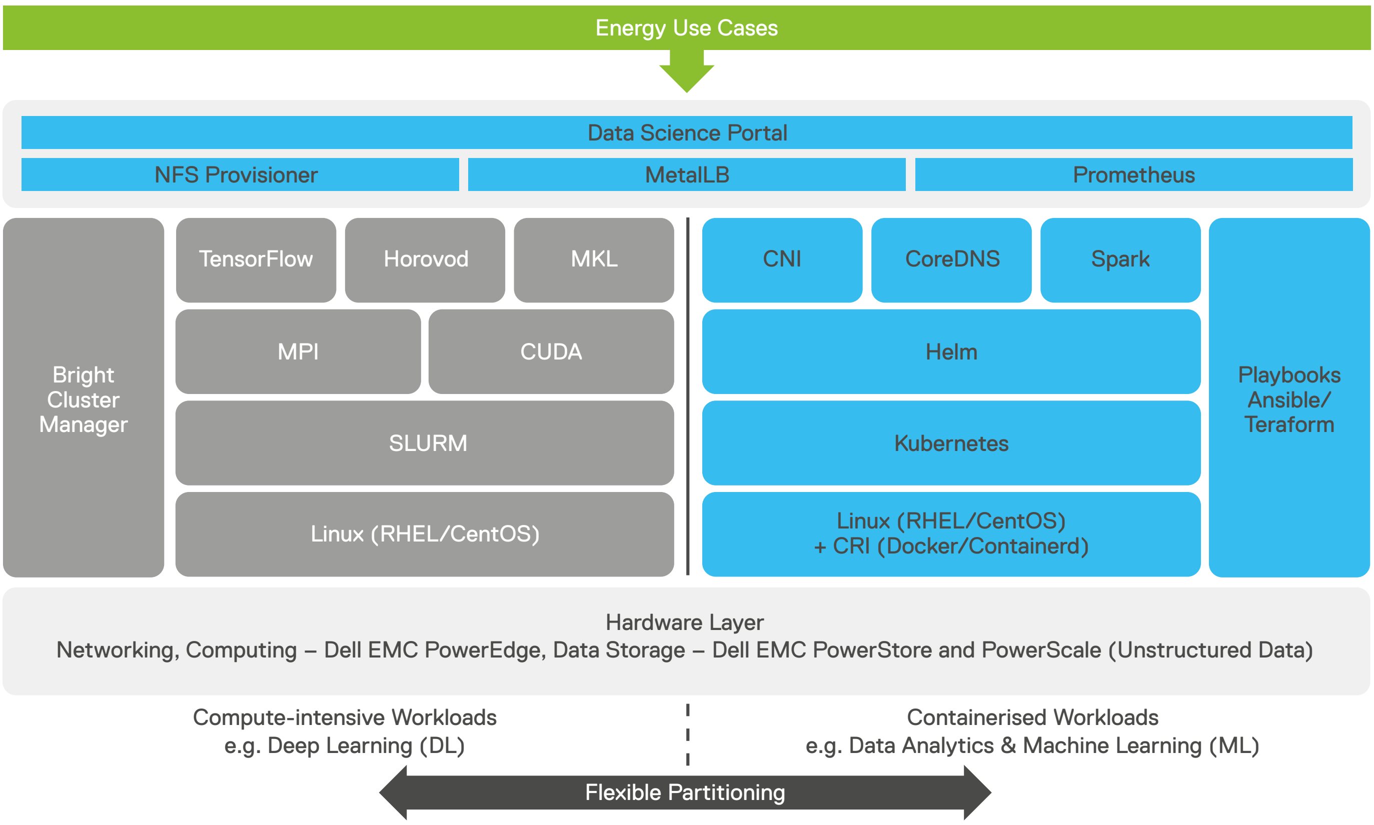
HPC workloads such as simulation runs and modelling can be compute-intensive, benefit from fast data interconnects and high-performing data management systems, and can take hours or days to run on a scheduled basis. Discovery-oriented AI and data analytics workloads on the other hand tend to be interactive, particularly during the model creation and training phases. In these cases, HPC resources are repeatedly spun up and down in a controlled but ad hoc manner driven by the outcomes of each run. Although all of these scenarios may also not necessarily be data intensive, they will require data preparation tools for ingestion, data quality checking and cataloguing.

So how can a unified HPC architecture support these apparently polarised requirements?



Unified HPC Architecture

The Unified HPC Architecture creates a single infrastructure pool of resources that can be dynamically assigned either to ‘left brain’ compute-intensive jobs that are managed by a resource manager or to the ‘right brain’ containerised machine learning or data analytics workloads that are facilitated by a container orchestration system.



Unified HPC Architecture – Example deployment

For example, consider the need for data scientists to rapidly analyse large-scale datasets for Oil & Gas upstream Production Optimisation or Electric Utilities Grid Load Balancing use cases. They would likely build early proof-of-concept models to demonstrate viability for future deployment, iteratively train complex neural networks to high accuracy, and finally deploy the trained models. They can start with Jupyter notebooks and Apache Spark scheduled on the Kubernetes partition to dig deep into the dataset, clean the data, discover features and patterns, and prepare the data for AI model training. From there, the data scientists can move to early model development in the Jupyter environment, where they can take advantage of the latest hardware accelerators to speed model development and hyperparameter tuning.

The data scientists can then use the compute-intensive partition to run neural network training in parallel using TensorFlow or PyTorch with Horovod to turn data into insights faster, and without needing to copy data from otherwise siloed systems. After obtaining a model that is accurate enough to deploy, the data scientists can return to the Kubernetes partition to finalise the optimisation and quantisation of the model, where the input values from the large data set are mapped to a targeted set of output outcome values.

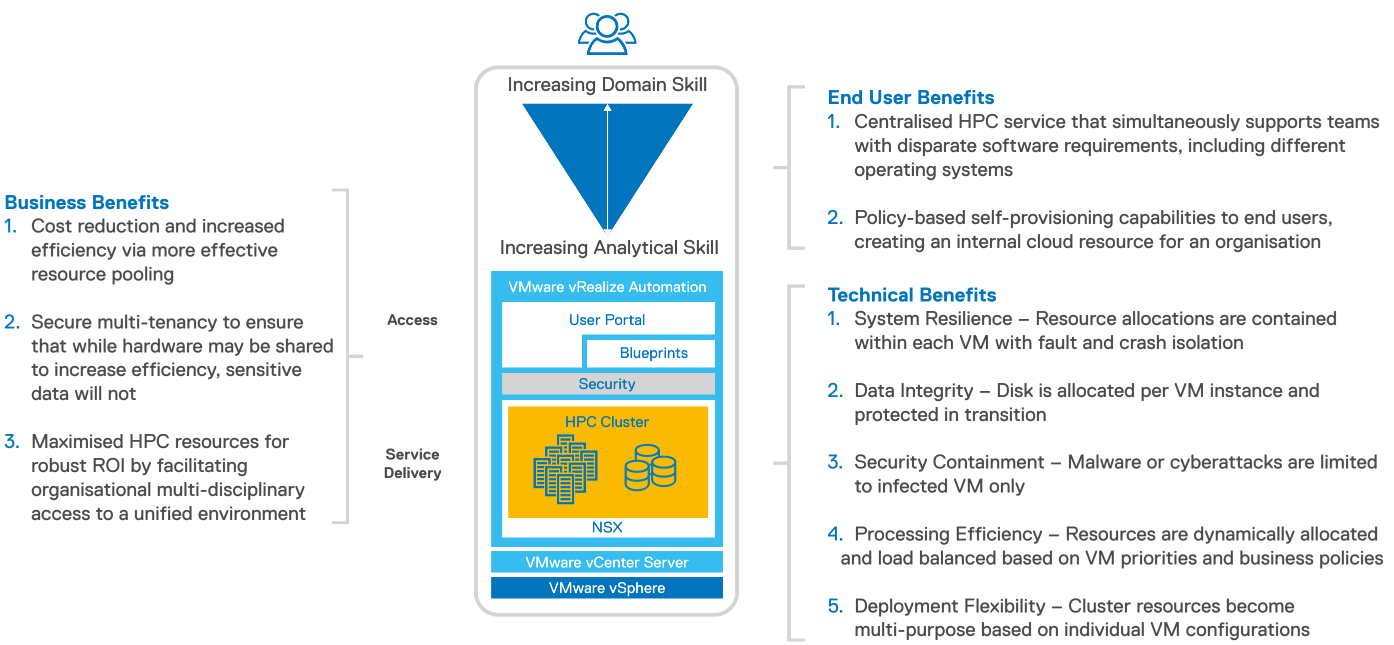
In addition to the ability to move projects from one partition to another depending on workload type, resources themselves can also be re-allocated from one partition to another to increase overall utilisation and to further optimise the performance of a workload in its preferred partition. For example, if additional computing resources are needed to deliver simulation results from an Electric Utilities windfarm production optimisation or Oil & Gas reservoir analytics run within a targeted time window for maximum business impact, the unified architecture enables nodes from the Kubernetes partition to be moved over to the SLURM partition if they are not currently being utilised.

The flexibility of the architecture also enables nodes to be added on-demand to increase overall compute capacity using Intel® Xeon® processor powered Dell EMC PowerEdge servers, and to scale data storage independently of compute resources using Dell EMC PowerStore or PowerScale data platforms, also powered by Intel® Xeon® processors.

The Value of Virtualising HPC Environments with VMware

Virtualising HPC environments enables Energy companies to achieve a high level of resource deployment flexibility and efficiency, workload execution resilience and advanced cyber protection. Building these attributes into the architecture from the onset creates a solid foundation on which to scale the HPC environment for what can only be an increase in use cases to be executed, data scientists and other analytics stakeholders to be supported and the volume of data to be processed. Eventually, no part of Energy value chains will be untouched by HPC, given the degrees of digitalisation and automation necessary to balance productivity, efficiency and carbon footprint.

Virtualising an on-premises HPC platform with VMware transforms the environment into a private cloud infrastructure. This adds self-provisioning, which empowers end-user data scientists and energy domain experts to instantiate and schedule the HPC resources they need for their projects in a controlled and predictable manner. IT staff productivity also increases as they can focus their efforts on monitoring resource usage for capacity planning and general administration without becoming a bottleneck to analytics-oriented business workstreams.
When an end-user instantiates a virtual HPC cluster, it is done by selecting the blueprint that matches the workload type. It specifies the required machine attributes, the number of machines, and the software that should be included in the Virtual Machine (VM), including operating system and middleware, enabling full customisation to their requirements. Defined and implemented by the central IT group, the blueprint approach also enforces corporate IT requirements such as security and data-protection policies.



Virtualised HPC Environment with VMware

In the past, HPC workloads have only been run on bare-metal hardware due to the performance penalty incurred when a layer of software is added between the operating system and hardware to support virtualisation. However, advances in both hypervisor and hardware virtualisation support in x86 microprocessors have yielded dramatic increases in performance for highly computation-intensive workloads.

Throughput workloads generally run at close to full speed in a virtualised environment — at less than 5% performance degradation compared to native with just 1–2% in many cases. This has been verified by VMware through tests of various applications across multiple disciplines and workload types.

A recent VMware study of virtualising HPC throughput computing environments demonstrated that with CPU overcommitment and the concept of creating multi-tenant virtual clusters on VMware vSphere®, performance of high-throughput workloads in a virtual environment can sometimes exceed the performance of bare-metal environments. The performance degradations of MPI workloads are often higher than throughput workloads due to latency requirements combined with intensive communication among processes. However, a performance study with VMware vSphere 6.5 on a Dell PowerEdge cluster has shown that performance degradations for a range of common MPI applications can be kept under 10%.

When small decreases in performance are weighed against significant operational benefits, virtualisation of HPC environments is becoming more common.

The Value of Mobile and Fixed HPC Workstations

HPC Workstations are powerful productivity data science tools that are suitable for Zone 1 Incubation discovery workloads as well as model preparation for Zone 2 Transformation workloads (see section 'Organising Energy Businesses to Maximise Success with HPC'). While a centralised HPC environment delivers resource efficiency, providing additional flexibility for data scientists to independently execute focused research, model preparation and early model training can be invaluable, particularly if workloads need to be executed in the field or on the go – example onsite during an Electric Utility windfarm pre-installation project, or Oil & Gas offshore pre-drilling reservoir modelling.

Dell's Precision 7000 series mobile workstations and 5000 and 7000 series tower workstations for HPC feature GPUs and hardware accelerators to help data scientists, developers and researchers quickly deploy AI frameworks with containers and get a head start with pre-trained models or model training scripts. They deliver state-of-the-art personal computing, including extensive memory and powerful Intel® processes to run scientific calculations, remote visualisation, 3D industrial designs, engineering simulations and digital content creation at peak performance to help save time and control costs.

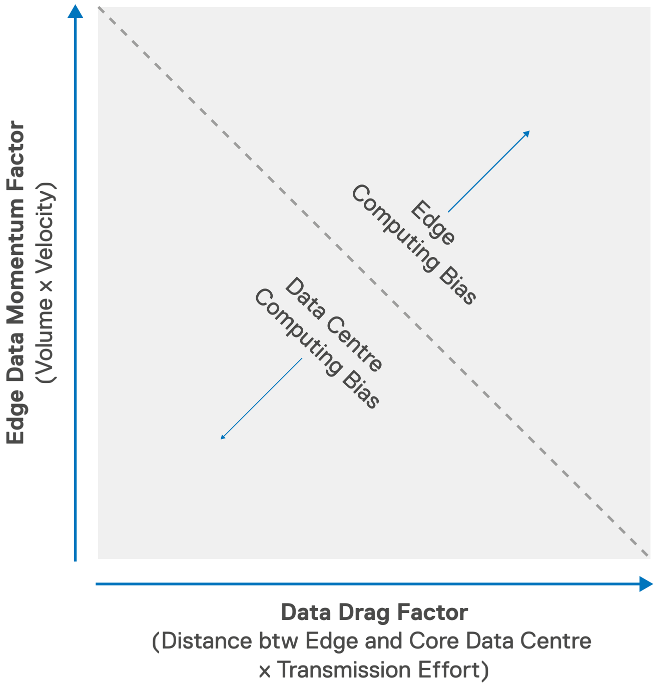
Dell also offers a specialised Data Science Workstation (DSW) portfolio powered by Intel® Xeon® processors and includes GPU-optimised XGBoost, TensorFlow, PyTorch and other leading applications. With this solution, data scientists can build their models on the DSW and train them using data residing on fast, high-performance Dell EMC PowerStore or PowerScale storage that also serves the unified HPC cluster. With this approach, data scientists will not need to bring data sets locally on to the DSW for training, further increasing productivity and reducing model training time.

Value of Edge HPC

A significant number of the example Energy use cases described in the section 'Energy Use Case Examples for HPC' utilise data originating from assets outside of the data centre. Of that figure, a substantial number again are workloads whose outputs are employed to adjust the behaviour of those assets in the field, but not all of them can yield practical results if every HPC workload is executed in a central data centre. There are challenges with data accessibility that require a coordinated distributed HPC approach, which in turn has an impact on infrastructure deployment decisions.

Data Challenges	Considerations	Measure
Physical Distance between field assets at the Edge and Data Centre	Networking has speed and capacity limits. The greater the distance the greater the latency.	**Data Drag Factor** – Distance between edge and core data centre x Transmission Effort* (*handling cost and geography challenges)
Proliferation of Data	Practically every field asset, including the workforce, is instrumented, generating data collectively 24x7 that needs monitoring	**Edge Data Momentum factor** – Volume of Data x Velocity* (*rate at which data is generated)

Distributed HPC does not mean that data is either all processed at the edge or all in the core data centre, but it does mean that the further away from and more difficult it is to transmit data to the core, the greater the need to add data management, compute and security infrastructure to the edge.



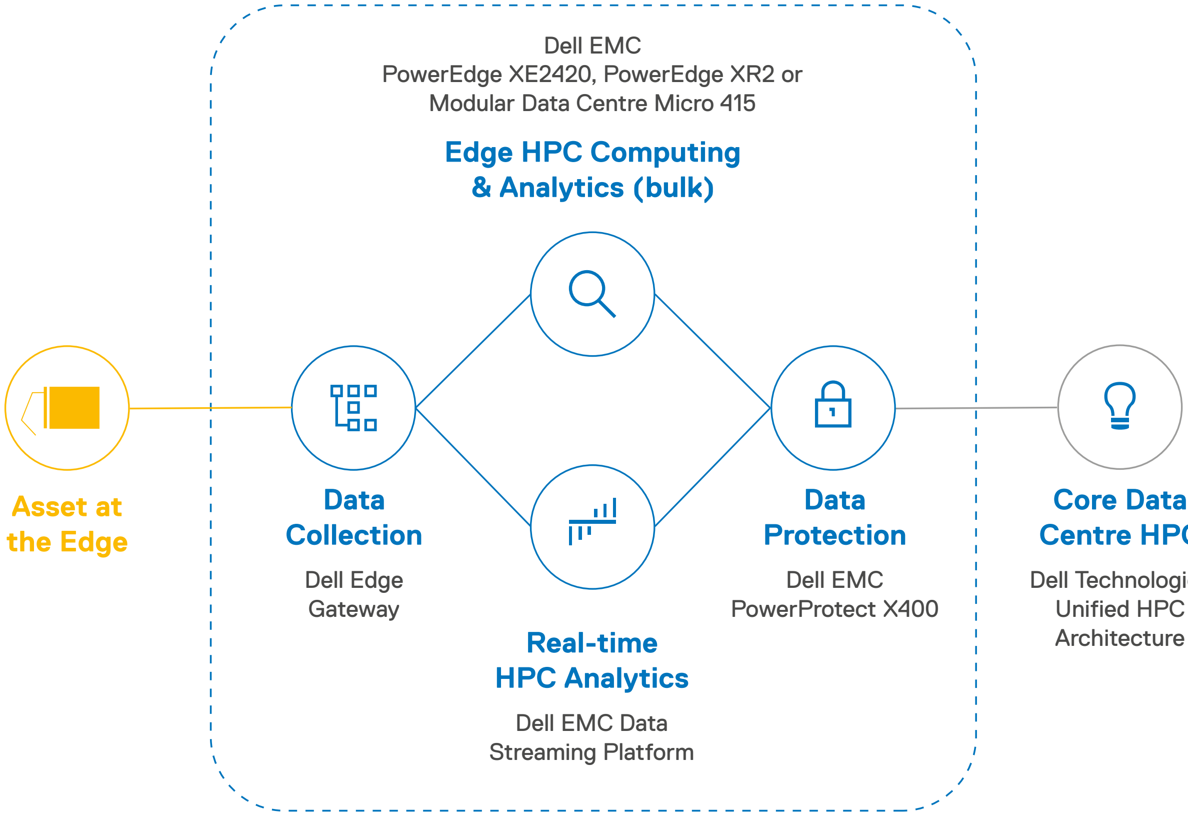
Factors influencing mix of edge and core data centre HPC

In some instances, it makes sense to deploy models that can be executed at the edge to drive automated adjustments to operations, and in others, it may be prudent to aggregate data at the edge into a summary format to reduce the amount of data to relay to the core data centre where the bulk of analysis will be performed. Ultimately, individual use cases may require a multi-staged approach that combines edge and core data centre HPC.

The challenges for deploying IT resources at the edge are even greater than those experienced with core data centre environments, and Dell Technologies offers a connected approach to mitigate these challenges.

Challenges at the edge include:

- **Locational:** Network connectivity may be limited
- **Environmental:** Open to the elements or housed in rugged environments
- **Spatial:** Needs to fit in tight spaces
- **Power:** Subject to restrictive power and cooling conditions
- **Operational:** Far away from skilled IT staff
- **Bandwidth:** Constrained, unpredictable or sporadic
- **Security:** IT needs to control and monitor security outside the confines of the data centre



Dell Technologies HPC Computing at the Edge – example

Dell Technologies offers a diverse edge portfolio that brings HPC closer to the edge data sources to ensure information is processed and actioned in line with operational needs rather than being constrained by environmental and distance-associated factors. (See how Calibr8 Systems helps energy companies transform the efficiency of their operations using Internet of Things technology supported by Dell Technologies Embedded & Edge Solutions).

Data Collection

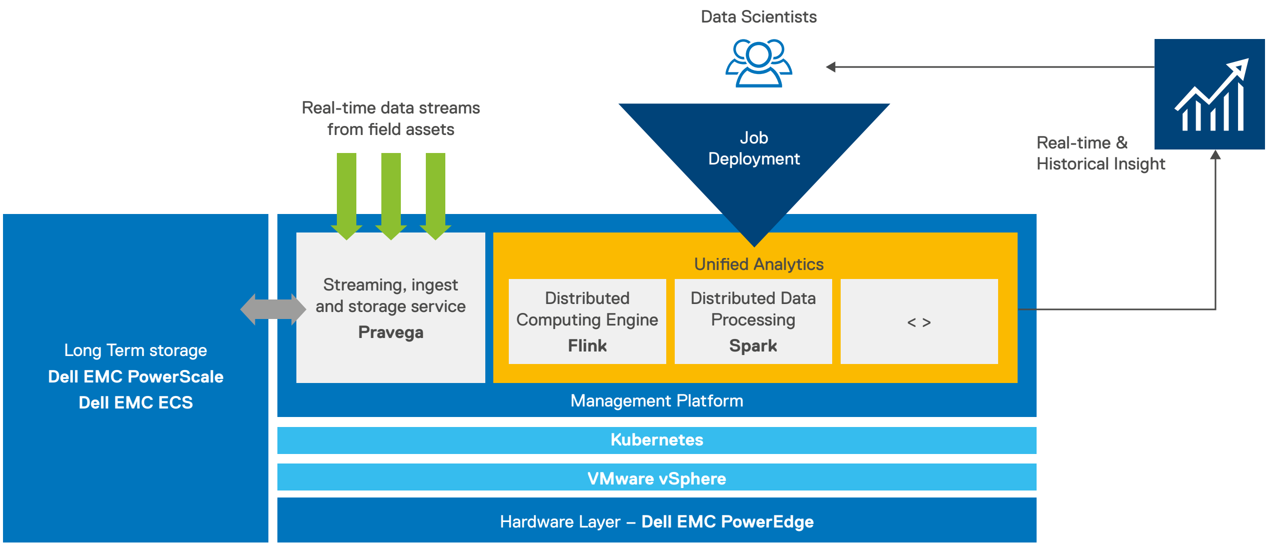
Dell Edge Gateways are ruggedised, intelligent devices that can collect and aggregate data from Energy field assets to support analytics at the edge of the network. They are an important first step in the edge data management and insight extraction process to prepare and route data to the appropriate HPC processing end-point.

Edge HPC Computing and Analytics for bulk data

For example, to support edge HPC computing and analytics for bulk data, the Dell EMC PowerEdge XE2420 solution provides high performance dense compute, simplified management and robust security for harsh edge environments, including extended operating temperature and dust tolerance. The Dell EMC PowerEdge XR2 solution is also built for rugged environments – temperature resilient, certified for shock, vibration, dust, humidity and electromagnetic interference (EMI). The Dell EMC Modular Data Centre Micro 415 offers a weather-hardened enclosure built to withstand extreme temperatures, rain, snow and physical impact. It is also equipped with smoke detection and fire suppression systems.

Real-time HPC Analytics at the Edge

The Dell EMC Data Streaming Platform is an elastically scalable platform for ingesting, storing, and analysing continuously streaming data in real time. The platform can concurrently process real-time and historical data in the same application, using data from sources such as IoT devices, industrial automation systems and live video. It also supports event-based streams crucial for driving use cases such as predictive maintenance, with the platform capable of processing millions of data streams from multiple sources while ensuring low latencies and high availability.



High Level Architecture – Dell EMC Data Streaming Platform

The management platform software integrates the other components and adds security, performance management, configuration and monitoring features. It includes a web-based user interface for administrators, application developers, and end users.

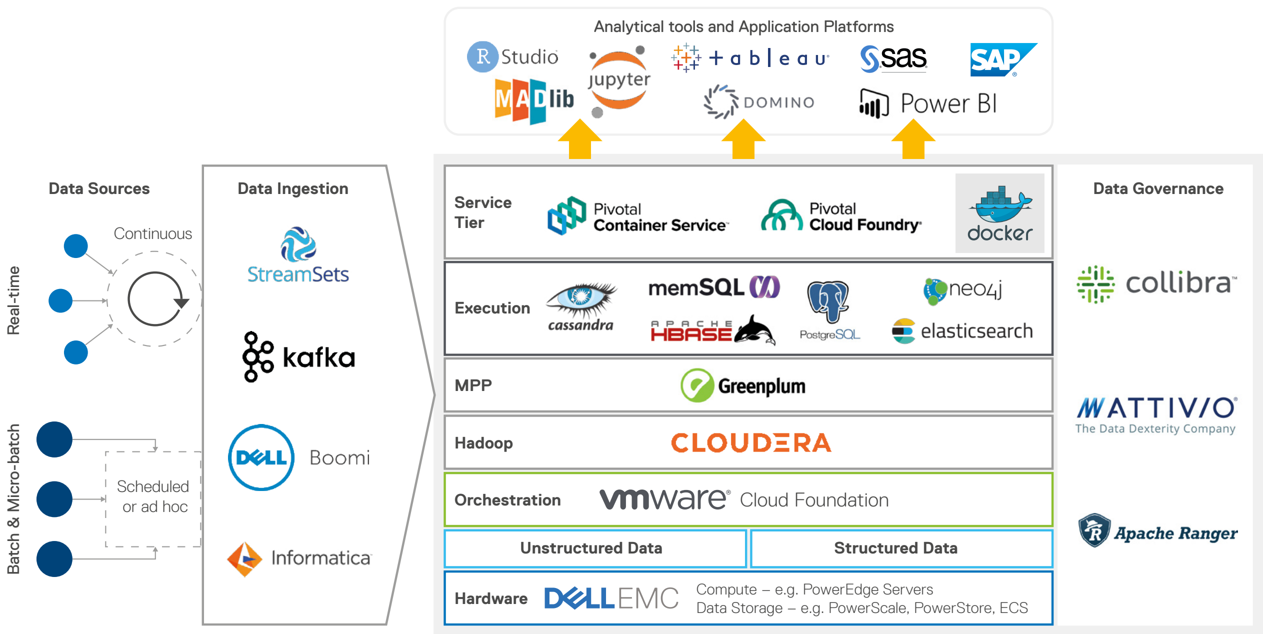
Data Protection at the Edge

The Dell EMC PowerProtect X400 offers backup, recovery and replication for environments that require scale-out data protection, including Kubernetes environments for HPC workloads. It offers scale-out and grow-in-place flexibility and the option of all flash or hybrid capacity, which is ideal for supporting the data proliferation that results from increasing edge-to-core digitalisation of Energy value chains. (Read how Rushmore Electric implemented the Dell EMC PowerProtect X400 Appliance to deliver around the-clock electricity while more efficiently managing fast-growing data).

Data Lake Considerations

Managing the large volume of data across operations in a Data Lake enables a consistent approach to data cleansing, cataloguing and security. While there is no silver bullet to the design of a data lake architecture, there are some key configuration components to consider, as highlighted in the following example below:

- Data Ingestion Framework – Public/Subscribe (Pub/Sub) data movement
- Hardware layer - Storage platforms for structured and unstructured data, plus compute resources
- Orchestration Layer – resource management
- Hadoop Layer – distributed big data processing
- Shared Data Platform that is scalable and facilitates MPP (massively parallel processing)
- Execution Tier for data manipulation
- Shared Services Tier for Analytical Tools and Application Integration



Example Data Lake components

Data Lake component highlights

The precise components that will make up a Data Lake configuration will depend on the specific requirements of an Energy business. Dell Technologies offers many of the key pieces necessary for a successful Data Lake implementation:

Dell Boomi

To accelerate business improvements and transform operations, Energy businesses require seamless connectivity between edge devices and application data. The Boomi platform is a flexible execution engine that enables enterprises to integrate and orchestrate services and manage workflows anywhere – on-premises, in the cloud or at the edge.

Dell EMC PowerScale

Dell EMC PowerScale is a scale-out NAS solution that offers the flexibility of a software-defined architecture with accelerated hardware innovations to harness the value of unstructured data. With PowerScale organisations can maximise the business value of their unstructured data at the edge, in the data centre or off-premises in the cloud.

Dell EMC ECS

Dell EMC ECS, the leading object-storage platform from Dell Technologies, has been engineered to support both traditional and next-generation workloads alike. Deployable in a software-defined model or as a turnkey appliance, ECS boasts unmatched scalability, manageability, resilience, and economics to meet the demands of modern business. ECS powers critical use cases such as line-of-business applications, websites, mobile apps, IoT data stores, analytics initiatives, long-term archives, and much more.

Dell EMC PowerStore

Dell EMC PowerStore's single architecture for block, file, and VMware vVols delivers the latest technologies to support an enterprise-class variety of traditional and modern workloads – from relational databases, to ERP and EMR apps, cloud native applications, and file-based workloads such as content repositories and home directories.

VMware Cloud Foundation

VMware Cloud Foundation is the hybrid cloud platform for managing VMs and orchestrating containers, built on full-stack hyper-converged infrastructure (HCI) technology. With a single architecture that is easy to deploy, VMware Cloud Foundation enables consistent, secure infrastructure and operations across private and public cloud. (See also Dell Technologies Cloud Foundation).

VMware Greenplum

Greenplum is an open-source massively parallel data platform for analytics, machine learning and AI. It can be used to rapidly create and deploy models for complex applications such as Cybersecurity, Predictive Maintenance, Risk Management and Fraud Detection.

Structuring HPC Resources for Efficiency with Cloud Computing

Being Clear about Cloud

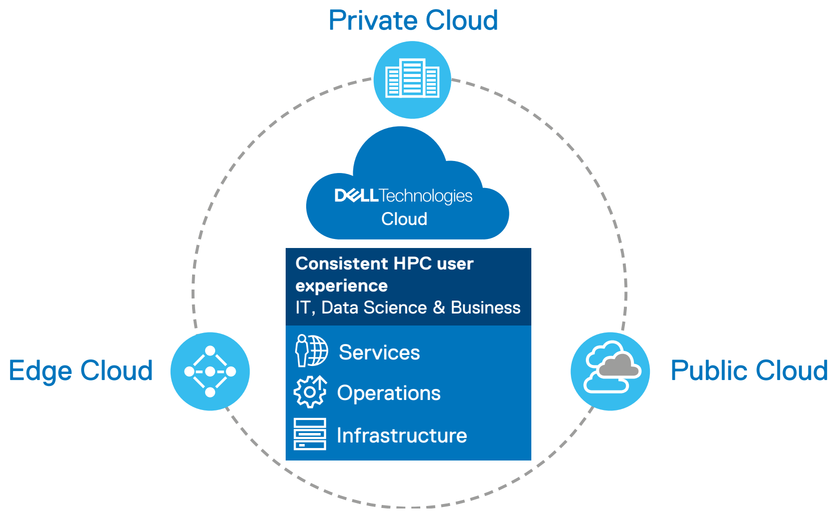
Cloud computing is undoubtedly one of the most widely discussed subjects at almost every level of an organisation, yet what is meant by 'cloud' may vary dramatically from person to person. More often than not, cloud is used to implicitly refer to 'public cloud', the kind of services offered by Amazon, Google, Microsoft and others. However, this loose way of thinking about cloud creates difficulties when you want to also talk about 'private' cloud and 'hybrid' cloud, so it is always worth level-setting what we mean by 'cloud'.

It is much clearer to define cloud computing as an operating model for provisioning IT resources to businesses rather than a destination. We can recognise that the primary benefits of cloud computing lie in the ability to abstract common functionality such as data access, data storage management, compute, networking and security into a set of integrated service interfaces that can be provisioned on-demand, and around which analytical workloads can be easily developed, executed and scaled. The conversation about cloud then becomes easier, because we are not unconsciously limiting our thinking to 'public' cloud.

We are instead free to discuss "how can we provide dynamic access to IT resources, while respecting the boundaries of business policies, regulatory requirements, workforce productivity needs and fiscal responsibilities?". The answer then lies in providing an environment that facilitates a mix of on-premises or third-party managed resources (private cloud), and the provisioning of off-premises public resources (public cloud) – but in a way that does not lock each workload into the platform it is first deployed. The hybrid cloud approach enables just that – the ability to move an application from one mode of cloud computing to another without needing to re-architect it. In other works, workloads can be executed in the resource environment that makes the best combined economic and productivity sense at a point in time, and this principle is just as viable for HPC resources as any.

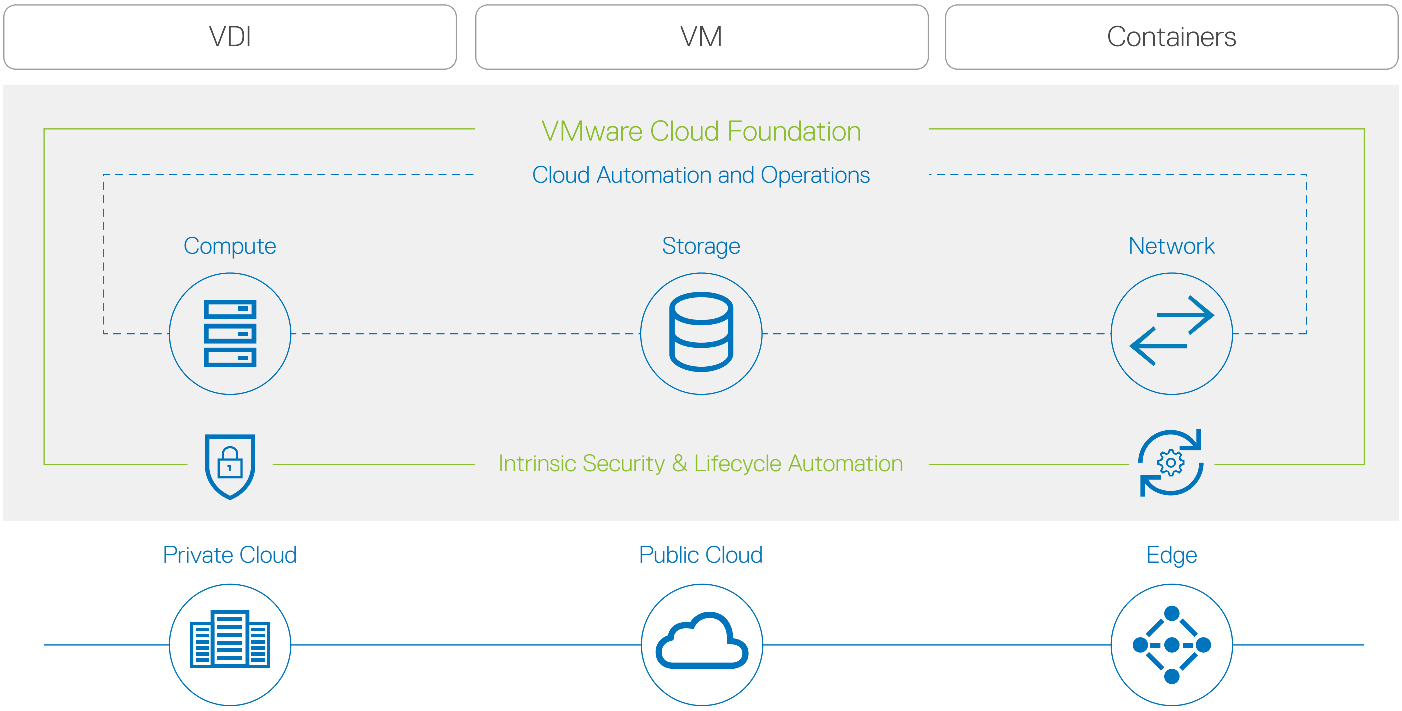
Dell Technologies Hybrid Cloud

Energy companies can leverage the Dell Technologies Cloud to provide a hybrid cloud operating model across public clouds, private clouds, as well as edge locations for HPC and other workloads. With consistent infrastructure, operations, and services across these environments and a single management console through VMware, operations can be streamlined, easily managed and with lower Total Cost of Ownership (TCO) across multiple clouds than a disconnected approach.



Dell Technologies Cloud Overview

Within the Dell Technologies Cloud, the HPC infrastructure leverages VMware Cloud Foundation to manage virtual machines (VMs) and orchestrate containers, built on full-stack Dell EMC hyper-converged infrastructure (HCI) technology. With a single architecture that is easy to deploy, VMware Cloud Foundation enables consistent, secure infrastructure and operations across edge, private and public cloud, and facilitates virtual desktop infrastructure (VDI) where appropriate for end-user productivity.



Dell Technologies Cloud leverages VMware Cloud Foundation

Choosing where to execute a particular HPC workload can be a complex decision. For example, if an Electric Utilities data scientist wanted to pursue Zone 1 Incubation research (see section 'Organising Energy Businesses to Maximise Success with HPC – Zone Prioritisation') on whether there was a relationship between the generation efficiency of solar farms and their proximity to bodies of water or other seemingly benign geographical features, initially spinning up some public cloud HPC resources for a short period of time with a small data set may be the practical and cost efficient thing to do. If a potential correlation is evident from initial runs, the data scientist can then easily shift the workload in-house for execution with a larger dataset on private cloud HPC in a Zone 2 Transformation configuration and eventually Zone 3 and/or Zone 4.

On the other hand, an Oil & Gas geoscientist located in Europe wishing to test a theory on some seismic data for a location in Africa may not be allowed to transfer that data to an HPC private cloud environment in Europe because of local data sovereignty laws, even though there is no prohibitive technical reason.

In another case, a business user may have been using public cloud resources to analyse customer behaviour clusters for several months, but when new personal attributes are included in the data sets, privacy policies may dictate that the workload should not be executed on public cloud resources.

However, with a hybrid environment like the Dell Technologies Cloud, the complexity of decisioning is significantly reduced as we remove questions about technical viable from the process. The choice becomes one of economics, compliance, resource availability and budget.

Alternative to Public Cloud HPC

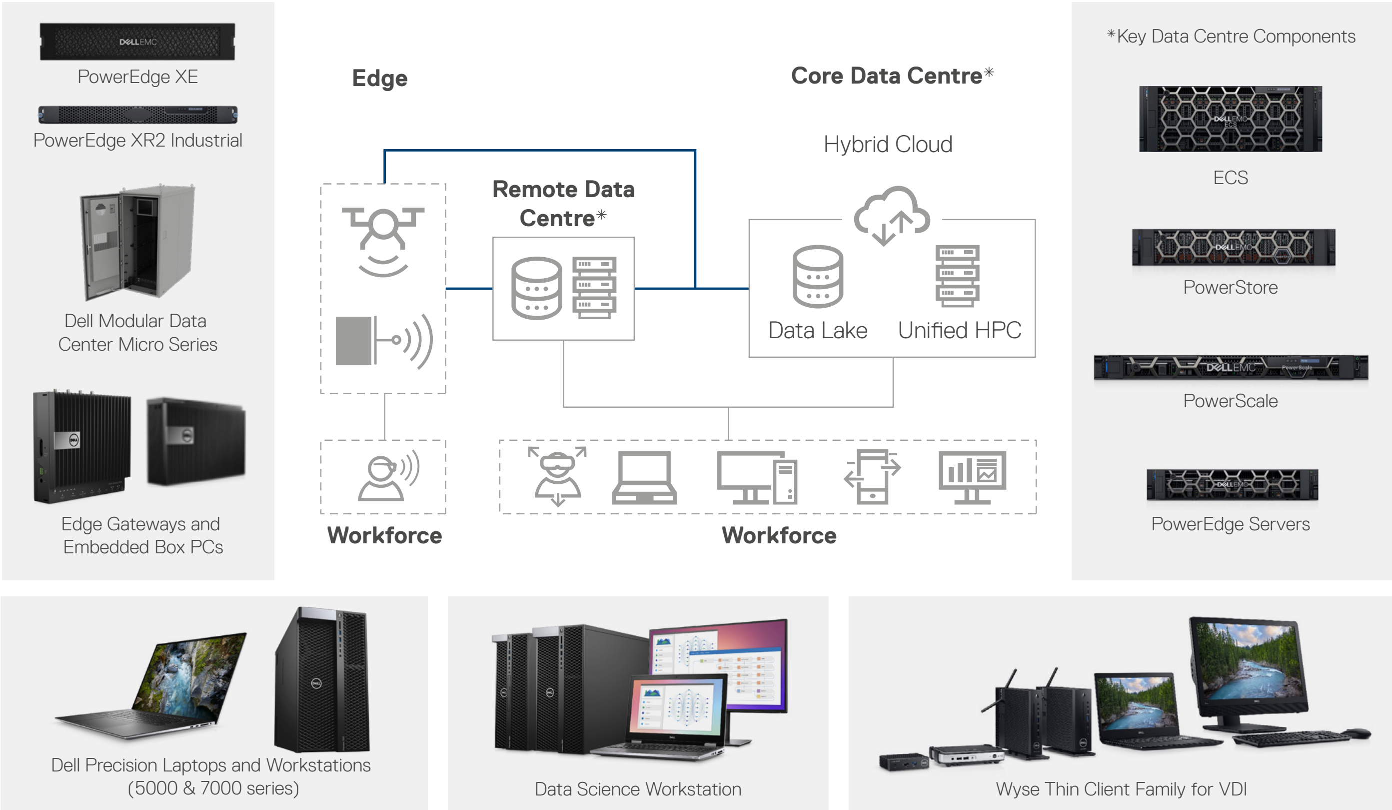
Occasionally, decisions fall into 'double-jeopardy', where a combination of IT resources and budget for on-premises HPC resources is not available, nor can public cloud resources be utilised because of compliance issues surrounding the nature of the data. In such a challenging scenario, Dell Technologies offers a range of flexible consumption models that enable on-premises implementation but with a resources-on-demand capability.

Dell Technologies Flex On Demand for example offers a metered usage model where organisations would only pay for what is consumed and take advantage of the ability to scale up or down. This enables them to pay monthly for current demands, while Dell Technologies assumes the risk to deploy sufficient capacity to accommodate desired flexibility and future scale.

Dell Technologies Hardware Components and Ready Solutions for HPC

Despite the differences between Oil & Gas and Electric Utility companies, the macro-level application of HPC across their connected digital operations is similar. With a comprehensive range of HPC options available, a global team of dedicated Dell Technologies HPC specialists work with Energy companies to define the right solutions for their needs, with clear roadmaps for expansion and innovation.

The schematic below illustrates some of the key hardware solutions for HPC, powered by 2nd Generation Intel® Xeon® Scalable Processors:



Key Dell Technologies Hardware Solutions for HPC

Although individual components may be selected to progressively build an HPC strategy, Dell Technologies and Intel® can accelerate the architecture design process with Ready Architectures (blueprints) created from a strong history of deploying and supporting thousands of implementations worldwide. Dell Technologies also offers a range of Ready Solutions for HPC Research, AI and Data Analytics that are preconfigured and optimised for specialised HPC workloads.

Notes

As mentioned in the section 'Structuring HPC Resources for Efficiency with Cloud Computing', Dell Technologies Cloud combines the power of VMware software and Dell Technologies infrastructure to provide a consistent operating model and simplified management across public Cloud, private Cloud and edge locations, eliminating silos through a single operational hub.

Also please refer to section 'The Value of a Unified HPC Architecture' for more on Unified HPC.

Hardware References

Data Centre – Core and Remote

Dell EMC PowerEdge Servers
PowerEdge servers provide the highest performance for a diverse set of workloads from the edge to the cloud to the core. As applications and workplaces become more complex, it becomes more important than ever for businesses to have end-to-end solutions that work together seamlessly.

Dell EMC PowerEdge Racks
PowerEdge rack servers provide the highest performance for a diverse set of workloads. They are designed to speed deployment and improve application performance for database, high-performance computing, and virtualisation environments. As workloads and workplaces become more complex, it becomes more important than ever for businesses to have end-to-end solutions that work together seamlessly. Powerful, simplified and automated OpenManage tools help manage large clusters easily and effectively, while robust security is built into the servers to protect from malicious activity.

Dell EMC PowerScale
Dell EMC PowerScale is a scale-out NAS solution that offers the flexibility of a software-defined architecture with accelerated hardware innovations to harness the value of unstructured data. With PowerScale organisations can maximise the business value of their unstructured data at the edge, in the data centre or off-premises in the cloud.

Dell EMC ECS
Dell EMC ECS, the leading object-storage platform from Dell Technologies, has been engineered to support both traditional and next-generation workloads alike. Deployable in a software-defined model or as a turnkey appliance, ECS boasts unmatched scalability, manageability, resilience, and economics to meet the demands of modern business. ECS powers critical use cases such as line-of-business applications, websites, mobile apps, IoT data stores, analytics initiatives, long-term archives, and much more.

Dell EMC PowerStore
Dell EMC PowerStore's single architecture for block, file, and VMware vVols delivers the latest technologies to support an enterprise-class variety of traditional and modern workloads – from relational databases, to ERP and EMR apps, cloud native applications, and file-based workloads such as content repositories and home directories.

Edge

Dell EMC PowerEdge XE
Dell EMC PowerEdge XE is a low-latency, short-depth edge server designed to support complex streaming analytics. It offers scalable performance in a dense form factor, secure and simplified management from edge to cloud to core, and high reliability in harsh environments outside the data centre.

Dell EMC PowerEdge XR2 Industrial
The Dell EMC PowerEdge XR2 Industrial is a high performance rugged server with workload acceleration and faster memory that is specifically designed to thrive in space constrained, rugged and harsh environments, at the edge.

Dell Modular Data Center Micro Series
The Dell Modular Data Center Micro series extends IT deployment in edge/non-data centre locations and are built to operate reliably in harsh environments.

Edge Gateways and Embedded PCs
From integration to automation, Dell EMC OEM & IoT enables you to innovate connected digital operations faster. Use IoT and embedded technologies to connect machines including in tough industrial environments, to improve efficiency and create new revenue streams. The Dell Technologies IoT Solution for Safety and Security enables you to plan the security and safety of your organisation's connected digital operations.

End-User HPC

Dell Precision line – laptops, workstations
Dell Technologies offers Data Scientists powerful computing resources to extract valuable insights from vast amounts of data. The Dell Precision line delivers fully integrated data analytics and AI hardware and software solutions - including high performance Precision laptops, workstations and a specialty Data Science Workstation (DSW).

Wyse Thin Client Family for VDI
Wyse Thin Client Family for VDI accelerates your cloud strategy and enhances virtual workspaces with intelligent unified management and the ultimate security solutions.

Contact Dell Technologies

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- **EMEA** - EMEA_HPC_Team@Dell.com
- **APJ** - APJ_HPC_Team@Dell.com
- **LATAM** - HPC_Latam@Dell.com

Appendix - Additional Resources

Dell Technologies - Make innovation real with High Performance Computing Solutions
www.delltechnologies.com/en-us/solutions/high-performance-computing/index.htm

Dell Technologies - Unlock the Value of your Data
www.delltechnologies.com/en-us/solutions/data-analytics/index.htm

Dell Technologies - Cloud-Enable your Edge
www.delltechnologies.com/en-gb/service-providers/edge-computing.htm#scroll=off

Dell Precision Workstations
www.delltechnologies.com/en-us/precision/index.htm

Intel® High Performance Computing
www.intel.com/content/www/us/en/high-performance-computing/overview.html

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