

DEEP Manufacturing

INDUSTRY ROUNDTABLE

INSIGHTS REPORT

*The Role of Additive Manufacturing in
Strengthening the Energy Supply Chain*

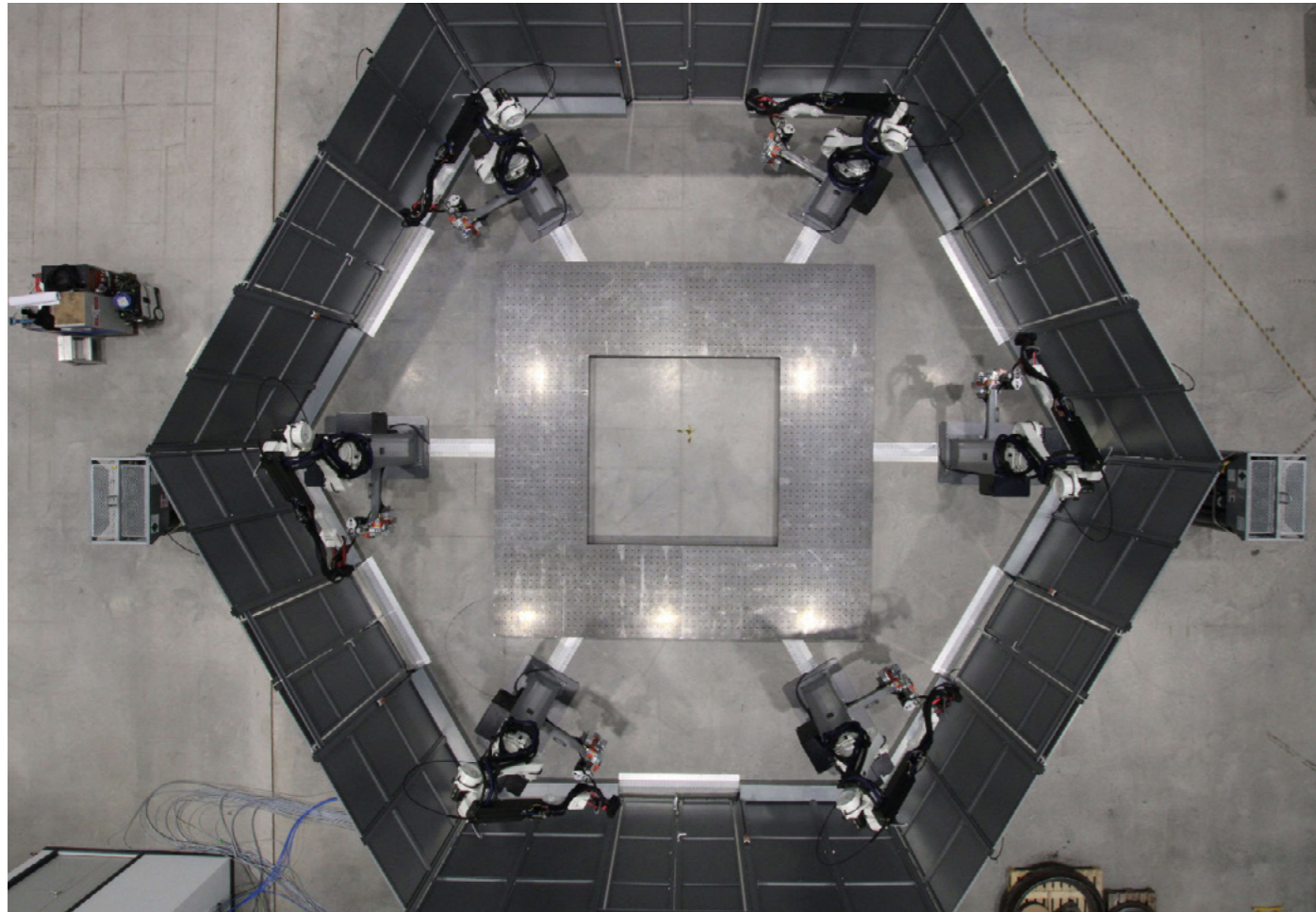


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DEEP Manufacturing's Multi-arm robot configuration, producing parts up to 6metres in diameter

ROUNDTABLE SYNOPSIS

This Roundtable gathered 30 energy industry and academic leaders tasked with identifying and deploying new technologies in the Middle East energy sector, to brainstorm the potential of additive manufacturing (AM) in bolstering supply chain resilience within the regional energy industry. Discussions covered the technology's impact on lead times, emissions reduction, cost savings, and the challenges of industry-wide adoption due to intellectual property (IP) concerns, certification processes, and traditional procurement habits. Experts from ADNOC, Emerson, SLB, Siemens Energy and others highlighted recent advancements and addressed the importance of collaboration, skill development, and alignment on standards to enable effective implementation. The Roundtable discussion emphasized a need for a mindset shift toward innovation and proactive measures to enhance industry-wide resilience.

FOREWORD

The Role of Additive Manufacturing in Strengthening the Energy Supply Chain



Peter Richards

Chief Executive Officer, DEEP Manufacturing

In today's complex energy landscape, resilience isn't just a buzzword – it's a necessity. At DEEP we're pushing boundaries by supporting human operations at significant ocean depths. When traditional manufacturing timeline couldn't meet our building essential, pressurized habitats, we turned to large scale Additive Manufacturing. This technology allowed us to produce large pressurized vessels, up to six meters in diameter, drastically reducing lead times and scaling production to meet demand.

Additive manufacturing has been transformative, but it's clear that our industry standards need to catch up. Building components to DNV standards ensures safety and compliance, yet challenges remain in standardizing and integrating AM printing across the sector. The recent supply chain disruptions, compounded by COVID-19, underscored the importance of local, on-demand manufacturing solutions. Digital passports for parts, for instance, allow us to maintain critical components and print them as needed, which strengthens supply chain resilience.

The potential of additive manufacturing is evident, but building confidence in this technology is the next frontier. As we move forward, companies must embrace innovation to build more adaptable, resilient operations. This is a tipping point for our industry, and it's time to fully leverage the benefits that Additive Manufacturing offers.

ROUNDTABLE EXECUTIVE SUMMARY

What's at Stake if the Energy Industry Delays Adoption of Additive Manufacturing

As global industries race to streamline supply chains and adopt innovative technologies, the energy sector faces a crucial choice: embrace 3D printing, also known as additive manufacturing, or risk falling behind. For an industry known for its cautious approach to new technologies, this decision isn't simply about keeping up with trends—it's about fortifying resilience, enhancing sustainability, and securing a competitive edge. Delaying the adoption of AM could have serious consequences, impacting operational efficiency, environmental impact, and long-term relevance.

One of the most immediate benefits of AM lies in bolstering supply chain resilience. The COVID-19 pandemic exposed the vulnerabilities of traditional supply chains, and the energy sector felt these disruptions acutely. Long lead times, dependency on global shipping routes, and limited local manufacturing capacity can lead to costly downtime and logistical challenges. AM can change this dynamic by enabling companies to produce parts on demand, close to where

they're needed, and often within hours. This capability is particularly valuable in remote or offshore operations, where a delay in receiving a critical part could halt production and lead to steep losses. By incorporating AM companies can build more agile and self-sufficient supply chains that are better equipped to handle unforeseen disruptions.

Beyond operational resilience, AM offers significant environmental benefits – a growing priority in a sector under increasing scrutiny for its role in global emissions. As the world transitions to cleaner energy sources, the industry faces mounting pressure to minimize its environmental footprint. Traditional manufacturing methods are often wasteful, relying on subtractive processes that cut away excess material, generating both waste and emissions. In contrast, additive manufacturing uses only the necessary materials, building components layer by layer and reducing waste considerably. Moreover, AM parts can be optimized for lighter weight, which can reduce the energy required for installation and operation. By proactively adopting

“By overcoming IP and regulatory challenges, the industry can position itself as a leader in sustainable and resilient manufacturing. The stakes are high, and the time to act is now.”

AM, energy companies can demonstrate a commitment to sustainability and align themselves with global emissions reduction targets, responding to rising expectations from investors, regulators, and the public.

However, achieving widespread adoption of AM isn't without challenges. Intellectual property (IP) concerns present one of the most significant barriers.

Many Original Equipment Manufacturers (OEMs) hesitate to share digital designs for 3D-printed parts, fearing loss of control over their IP. But the industry cannot afford to let IP issues stand in the way of progress. Collaborative frameworks – such as digital “passports” that protect IP while allowing local manufacturing – can provide a way forward. By establishing these protections, the energy sector can unlock the advantages of 3D printing without compromising proprietary knowledge, fostering a more collaborative and adaptable industry ecosystem.

Certification and standards also pose obstacles to adoption. The energy sector is subject to stringent regulations that ensure the safety and reliability of every component. Currently, certification processes are largely built around traditional manufacturing, and each AM part must meet these standards to be viable. Establishing new standards and certification processes for printed parts will

require cooperation between companies, regulators, and standards bodies. By taking the lead in shaping these standards, energy firms can ensure that parts meet industry requirements while fostering an environment of innovation.

The cost of inaction is clear: as other sectors like aerospace and automotive embrace AM, the energy industry risks being left with outdated processes and technologies. These industries have successfully navigated IP and certification challenges, demonstrating that AM can be scaled even in highly regulated environments. If energy companies delay, they risk losing the flexibility and resilience that competitors in other sectors are already achieving with additive manufacturing.

In conclusion, Additive Manufacturing is more than a technology trend – it's an essential tool for the energy sector to address today's supply chain vulnerabilities, reduce its environmental impact, and enhance operational adaptability. By overcoming IP and regulatory challenges, the industry can position itself as a leader in sustainable and resilient manufacturing. The stakes are high, and the time to act is now. Embracing AM will empower the energy sector to navigate future challenges with innovation and responsibility, securing its place in a rapidly evolving global energy landscape. ■

CONCLUSION & NEXT STEPS

The discussions highlighted the importance of leveraging additive manufacturing to meet rising global energy demands while fostering supply chain resilience and sustainability. Collaborative frameworks, IP solutions, and standardization efforts will be key to overcoming current adoption barriers. Moving forward, the industry should prioritize:



1. Investment in Training and Skill Development

Expand partnerships with universities and technical institutions to prepare professionals for additive manufacturing and digital design.



2. Enhanced Collaboration on Standards

Align on industry-wide standards and certification processes to ensure quality and consistency across parts and materials.



3. Innovative Financing Models

Address the financing gap by engaging global banks and alternative funding sources to support both traditional and renewable projects.



4. Promoting Digital and Physical Infrastructure

Establish virtual warehouses and local post-processing facilities to streamline additive manufacturing and shorten lead times.



5. Environmental Impact Assessments

Track sustainability metrics, including emissions and resource use, across the entire additive manufacturing lifecycle to optimize environmental benefits.

By following these steps, stakeholders can support a balanced energy landscape that meets immediate needs and drives sustainable growth, positioning the industry as a leader in technological advancement and environmental stewardship.

SOUNDINGS

“Certification is complex because every part, machine, and material requires certification. If you change even one component, the entire certification process must be redone, which adds to the industry’s hesitation in adapting additive manufacturing. Repeatability is also a concern. If you print a part today and an identical part tomorrow using the same material and machine while may be changing its location or orientation within the build plate, will they be identical?”

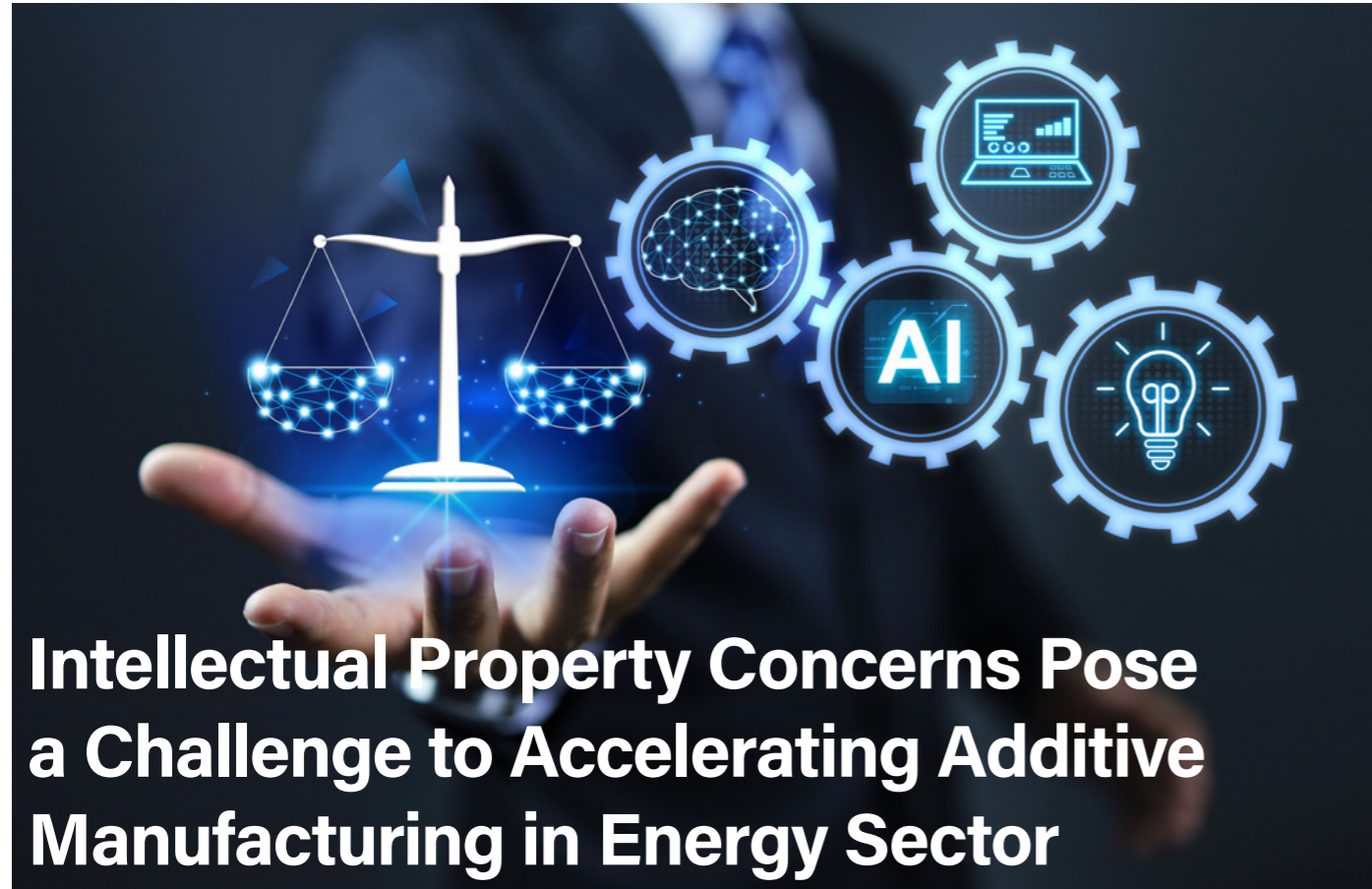
Dr. Rashid Abu Al Rub,
 Director, Advanced Digital & Additive Manufacturing (ADAM) Center & Professor,
 Mechanical & Nuclear Engineering, Khalif University

“At Emerson, we recognize that integrating additive manufacturing for on-demand parts at third-party sites presents challenges such as digital file security, quality control, and repeatability. Our approach is to ‘think big, start small, and scale fast,’ yet we proceed with caution to ensure consistent quality and sustainable growth. Unauthorized third-party use can compromise quality and consistency, so it’s essential to collaborate across the ecosystem - protecting the IP rights of OEMs, third-party providers, and end-users alike - to optimize this technology securely and effectively.”

Prakash MS, VP for Africa at Emerson

“At Siemens Energy, we’ve successfully applied additive manufacturing in power generation, specifically with gas turbines, where it enables consistent, repeatable processes that reduce operational risk across fleets. Additionally, additive methods allow us to create complex, optimized designs - like turbine blades with advanced curves - that traditional manufacturing can’t replicate. The oil and gas industry, with similar technological needs, could benefit greatly from these advancements, opening opportunities for improved efficiency and innovation.”

Thomas Soulas, Head of Technology and Innovation, Innovation Center Abu Dhabi, Siemens Energy



Intellectual Property Concerns Pose a Challenge to Accelerating Additive Manufacturing in Energy Sector

As the energy industry explores the transformative potential of AM, intellectual property (IP) concerns have surfaced as a significant barrier to widespread adoption. While additive manufacturing offers promising benefits such as reduced lead times, on-demand production, and decreased waste, it also introduces complex challenges related to IP protection.

Many companies in the supply chain are cautious about fully committing to this technology, fearing unauthorized use of their digital designs and the potential loss of market control. This hesitation has spurred debate across the industry about how to protect IP effectively while still harnessing the advantages of AM.

For Original Equipment Manufacturers (OEMs) in particular, IP protection is paramount. Traditionally, OEMs produce and deliver physical parts with well-defined specifications and proprietary features. With AM, however, companies often need to share digital files of their designs to enable local production, which introduces vulnerability to unauthorized distribution and use. The risk of losing control over these designs – or worse, having them copied and used by competitors – makes many OEMs reluctant to embrace AM as a core part of their manufacturing and distribution strategies. Although AM opens up new revenue models, such as licensing digital files rather than physical parts, the fear of compromised IP has left many companies wary of moving forward.

In response to these challenges, companies have begun exploring methods to safeguard IP in the context of AM. One emerging solution is the use of “digital passports”—secured digital files that allow OEMs to retain control over their designs even when shared for localized production. Digital passports restrict access and use to approved facilities and can offer time-limited licenses or access controls to prevent unauthorized copying. Additionally, some companies are using blockchain technology to track and authenticate the use of digital files, providing a secure record of how and when designs are used.

These measures represent an innovative approach to IP protection in the digital age, but they require collaboration across industry stakeholders to standardize their use effectively.

Collaboration is, in fact, essential if the energy industry is to overcome the IP challenges associated with AM – stakeholders aligning on IP standards and licensing practices could foster greater confidence among OEMs, suppliers, and end-users.

By developing agreed-upon frameworks for sharing and using digital files, companies could reduce the risk of IP theft and encourage wider adoption of AM technology. However, reaching such an agreement is easier said than done. IP concerns are deeply rooted, with many companies fearing that opening up their designs, even within controlled parameters, could eventually erode their competitive advantage.

Another hurdle lies in the lack of universal standards for AM applications in sector. Currently, existing standards are primarily focused on traditional manufacturing, limiting the full potential of additive manufacturing. New standards specific to AM parts would provide a foundation for safe and reliable use in critical applications, but they would also need to address IP protections in the certification process. This dual focus on quality and IP security would enable OEMs and end-users alike to have greater assurance in the technology.

The debate around IP is a double-edged sword for the industry. While IP protection is essential to maintain competitive advantage and ensure quality, it has also slowed progress, with many companies reluctant to take on the perceived risks. Nevertheless, as the industry continues to explore the potential of Additive Manufacturing there is a growing recognition that collaboration on IP and standardization could ultimately unlock the technology’s full benefits. By establishing trust and finding common ground on IP protections, the energy sector can better position itself to harness the advantages of AM and transform its approach to manufacturing.

In conclusion, addressing IP concerns in AM requires innovation and collaboration. As stakeholders work towards balanced solutions that protect proprietary knowledge without stifling progress, the oil and gas industry stands at a crossroads. Success in navigating these IP challenges will determine how effectively Additive Manufacturing can deliver the resilience, efficiency, and sustainability that the industry urgently needs. ■

ADNOC GAS CASE STUDY

ABOUT ADNOC GAS

ADNOC Gas, listed on the ADX, is a world-class, large-scale integrated gas processing company operating across the gas value chain, from receipt of feedstock from ADNOC through large, long-life operations for gas processing and fractionation to the sale of products to domestic and international customers. ADNOC Gas supplies approximately 60% of the UAE's sales gas needs and supplies end-customers in over 20 countries.

ADNOC Gas Using 3D Printing to Manufacture

Critical Replacement Components on Demand:

- Company set to save \$50 million using one of energy industry's largest digital libraries of critical components
- 3,500 parts scanned and stored in a secure digital warehouse, ready to be printed when required
- 3D printing reduces lead times for replacement components by 50%, while also eliminating overseas shipping and lowering CO₂ emissions

ADNOC Gas has developed one of the energy industry's largest digital libraries of critical components, which can be manufactured on demand using advanced three-dimensional (3D) printing technology. Over 3,500 items have been scanned and stored in a secure digital warehouse, generating an expected benefit to ADNOC Gas of \$50 million by 2028.

The use of 3D printing offers an advanced digital solution for producing high quality components quickly to ensure uninterrupted operations and supports ADNOC's broader strategy to accelerate the deployment of advanced technologies and artificial intelligence (AI) to drive greater value. The process, called additive manufacturing but more commonly known as 3D printing, has cut production

lead times by 50%, significantly reducing operational down time and allowing for greater inventory flexibility and responsiveness to market demands.

The innovative 3D printing technology, provided by Immensa, a UAE-based market leader in additive printing and digital warehousing, has been used to manufacture critical replacement components at ADNOC Gas' Das Island and Habshan gas processing sites. This innovative approach has eliminated the need for overseas shipping, cutting CO₂ emissions, and drastically reduced on-site inventories.

Dr. Ahmed Alebri, Chief Executive Officer of ADNOC Gas, said: "3D printing provides an advanced digital solution for designing and producing components, optimizing the company's supply chain, enhancing performance, and reducing costs. It enables the creation of complex geometries and precise features impossible to achieve with traditional manufacturing methods. By leading the way in integrating additive manufacturing into our operations, we are driving forward operational excellence and delivering exceptional value to our stakeholders."

At its Das Island site, ADNOC Gas has successfully replaced air compressor impellers with 3D printed impellers, proving the feasibility of using the technology for complex, high-value rotating parts. Meanwhile, at its Habshan site, hundreds of components have been scanned and digitally stored, ready to be 3D printed on demand using polymers or metals.

"By leading the way in integrating additive manufacturing into our operations, we are driving forward operational excellence and delivering exceptional value to our stakeholders."

**Dr. Ahmed Alebri,
Chief Executive Officer, ADNOC Gas**

ADNOC Gas' use of 3D technology paves the way for further innovation across the company. It is exploring onsite 3D manufacturing to optimize its operations and cut CO₂ emissions. It is also partnering with Immensa to create and optimize 3D printing solutions specifically for the energy industry.

Innovation and technology have long been the hallmarks of ADNOC Gas, and it is harnessing the power of big data analytics, supercomputing, and artificial intelligence (AI) to optimize efficiency and sustainability across its operations and deliver greater shareholder value.

In addition to 3D printing, ADNOC Gas has developed and deployed multiple advanced digital solutions, including AI and machine learning. Through these data driven solutions and the insights they provide, the company is optimizing processing and maintenance operations, enhancing efficiency, improving its sustainability performance, and driving competitive advantage. ADNOC Gas expects AI to deliver benefits of \$400 million a year for the next five years. ■

TOP 10 TAKEAWAYS



Supply Chain Resilience

AM offers the ability to produce parts on-demand, reducing dependency on long supply chains and minimizing risks associated with delays. This is particularly valuable for remote or offshore operations where timely access to parts is essential. By localizing production, companies can enhance supply chain resilience and operational continuity.



Environmental Benefits

Additive manufacturing builds parts layer by layer, using only the required materials, which significantly reduces waste compared to traditional manufacturing. This efficiency supports industry sustainability goals, lowering emissions and resource use. By optimizing materials and minimizing waste, AM aligns with global environmental targets and industry standards for eco-efficiency.



Digital Passports

Digital passports store blueprints for parts that can be printed on demand, improving operational agility and reducing lead times. These digital

solutions provide companies with better control over part availability and enable more responsive, flexible manufacturing processes, especially in regions or operations that rely on immediate part replacement.



Standardization & Certification

For additive manufacturing to reach full industry integration, new standards and certification processes must be developed. Current standards focus on traditional manufacturing, which limits adoption of AM. By establishing specific guidelines for additive manufacturing, the industry can ensure that printed parts meet strict safety and reliability requirements.



IP Concerns

Intellectual property protection is critical to encouraging OEMs to share digital designs for AM. IP protections, such as digital safeguards, allow companies to retain control over proprietary parts while enabling broader use of additive manufacturing. Addressing these IP concerns can foster collaboration and speed up industry-wide adoption.



Customized Production

Unlike traditional manufacturing, Additive Manufacturing supports tailored production, allowing companies to



In-Country Value (ICV)

By establishing local manufacturing capabilities through Additive Manufacturing, companies can increase their contributions to local economies, supporting In-Country Value (ICV) objectives. This shift to local production reduces reliance on imports, creates jobs, and strengthens the regional supply chain, helping companies align with national development goals and local content requirements.



Skill Development

Embracing AM will require a specialized workforce with expertise in digital and additive manufacturing. Training programs and university partnerships are essential for developing these skills, ensuring the industry has the necessary talent to operate and innovate with this technology. Investing in workforce development can help close the digital skills gap.

design parts specific to their operational requirements. This flexibility enhances equipment performance and optimizes resources, enabling energy companies to address specialized needs with precision. Customized production also simplifies assembly and reduces reliance on complex multi-part components.



Cross-Industry Inspiration

Industries like aerospace and automotive have successfully integrated Additive Manufacturing providing valuable insights for the energy sector. These sectors overcame similar challenges, such as certification and IP concerns, demonstrating scalable solutions for additive manufacturing in regulated environments. Learning from these industries offers a viable path for the industry to accelerate adoption.



Digital Warehousing

Digital warehousing, where part designs are stored digitally and printed as needed, supports on-demand manufacturing and reduces the need for large physical inventories. This approach enables companies to efficiently manage parts, especially for legacy or low-demand components, and enhances flexibility in responding to operational needs with minimal stockpiling.

This approach positions the energy sector to adopt additive manufacturing, enhancing resilience and sustainability while adapting to a rapidly evolving energy landscape.



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