Manufacturing

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What's at Stake for Supply Chain Resilience & Competitiveness if Energy & Industrial Sectors Fail To Move Beyond Pilot Projects to Full-Scale Deployment of Advanced Manufacturing?

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FOREWORD

From Pilot to Deployment: Manufacturing's Moment of Truth

Peter Richards
Chief Executive Officer, DEEP Manufacturing

The time for pilot projects has passed. The manufacturing sector – particularly within energy and industrial domains – must now embrace full-scale deployment of advanced manufacturing technologies if it wishes to remain competitive and resilient.

At DEEP, our journey began with a bold vision: to build subsea habitats capable of sustaining human life for extended periods under extreme conditions. That vision demanded engineering innovation at a scale traditional method could not support. We turned to additive manufacturing, specifically wire-arc technology, to produce ultra-large pressure vessels certified by DNV for human occupation — at a fraction of traditional lead times. What was once theoretical is now being deployed, not piloted.

The lesson is clear: the transition from "proof of concept" to "real-world production" requires courage, investment, and confidence in new technology. We are witnessing aerospace and defense sectors move faster than oil and gas because they've learned to trust innovation underpinned by robust certification. Yet in many industrial circles, conservatism persists — a reflex to "do things the way we always have." That mindset is no longer sustainable.

Advanced manufacturing is not just about speed; it's about design flexibility and supply chain resilience. The ability to blend materials — from duplex steels to exotic alloys — within a single build process enables unprecedented complexity and efficiency. We can

now produce qualified, certified components in half the time, supporting industries where every day of downtime equates to millions in lost revenue.

But technology alone is not enough. Ecosystems matter. Success depends on collaboration between manufacturers, classification bodies, regulators, and customers. Standards must harmonize across industries; people must be trained; and confidence — institutional and cultural — must replace hesitation. Above all, sustainability must be woven through the process. Additive manufacturing inherently reduces waste by producing only what is required, aligning production with purpose.

The opportunity is before us. The choice is between innovation or inertia. As DEEP Manufacturing's own progress shows, the future of manufacturing will belong to those who deploy, not those who merely demonstrate.

TOP 5 NEXT STEPS — CONSENSUS TAKEAWAYS

1. Accelerate Standardization and Certification

Industry players, regulators (DNV, Bureau Veritas), and operators must harmonize certification processes (API, ASME, DNV equivalence) to shorten the path from prototype to deployment. Joint industry projects (JIPs) can unify standards across regions and sectors.

2. Build Digital Inventories and Reverse Engineering Hubs

Companies should digitize legacy parts — creating secure "digital passports" to enable on-demand printing anywhere. This shifts asset management from physical warehouses to cloud-based spare part ecosystems.

3. Promote Ecosystem Partnerships and Shared Facilities

Operators, manufacturers, and governments should form consortiums to co-invest in additive manufacturing hubs, ensuring consistent demand and risk-sharing. Regional power and logistics advantages (like the UAE) can anchor these clusters.

4. Train and Certify the Workforce of the Future

Investment in human capital — operators, materials engineers, and digital designers — must keep pace with technology. Academic partnerships (e.g., Khalifa University) are vital to develop local expertise.

5. Embed Sustainability and Circularity

Manufacturing must align with environmental goals: print only what's needed, recycle obsolete stock, and reduce energy intensity. A circular, data-driven manufacturing model is not just efficient — it's essential for global competitiveness.

EXECUTIVE SUMMARY

The conversation about advanced manufacturing has moved beyond the language of innovation to the language of survival. Across industries, the question is no longer whether to adopt technologies like additive manufacturing, but how fast they can be deployed at scale. The energy and industrial sectors, long known for their caution, are realizing that the stakes have shifted. Competitiveness, resilience, and sustainability all now depend on breaking out of the pilot phase and moving into real-world implementation.

Building resilience through localized, on-demand production

The argument for advanced manufacturing begins with its impact on supply chain resilience. Recent years have shown how fragile global production networks can be. From pandemics to geopolitics, disruptions have exposed the limitations of traditional supply models. Additive manufacturing, with its ability to produce complex, certified parts in weeks rather than months, offers an answer. When components can be built locally and on demand, industries gain control over their timelines and reduce dependence on distant suppliers. This shift is not theoretical—it is already underway. Companies that once relied on long international supply lines are turning to digital inventories and regional facilities capable of fabricating critical equipment within days.

Certification and trust unlock industrial-scale adoption

The benefits extend far beyond speed. Certification, once a barrier, has become an enabler. Organizations such as DNV now verify pressure vessels and other mission-critical parts produced through additive processes, proving the technology's readiness for industrial use. This validation reassures cautious sectors like oil and gas, where the cost of failure is measured not only in money but in safety and reputation. As trust grows, so does the willingness to integrate additive methods into everyday operations.

Yet despite these advances, adoption remains uneven. Aerospace has embraced additive manufacturing out of necessity, driven by performance demands and logistical challenges.

Oil and gas, by contrast, often remains bound by legacy practices. The technology exists, the standards exist, and the business case is clear, but the mindset has been slow to evolve. Risk aversion—disguised as prudence—continues to slow transformation. The irony is that the industries most exposed to disruption are often those most reluctant to change.

What happens if they do not act? The consequences are already visible. Supply chain bottlenecks are reappearing as global demand for both hydrocarbons and low-carbon energy technologies surges. Without the agility that advanced manufacturing provides, companies will face higher costs, delayed projects, and even energy insecurity. The next decade will not tolerate inertia. Industrial players must find ways to be leaner and faster, and that requires production systems designed for flexibility.

From stockpiles to smart supply: the rise of the digital warehouse

One of the most important shifts happening today is the rethinking of inventory management. For decades, the answer to supply risk was to stockpile—warehouses filled with components "just in case." The problem is that this model ties up vast amounts of capital and creates waste when parts expire or corrode unused. Additive manufacturing introduces a new paradigm: build

only what you need, when you need it. A digital warehouse replaces physical storage, allowing companies to maintain virtual inventories of certified component designs. When a part is required, it can be printed at a nearby facility using standardized "digital passports." The result is efficiency, sustainability, and lower costs.

Artificial intelligence strengthens this system further. Predictive algorithms can forecast which components are likely to fail and preemptively schedule their replacement. Machine learning models can analyze consumption patterns across fleets or facilities, ensuring that manufacturing

happens only where and when demand arises. This integration of AI and additive manufacturing transforms supply chains from reactive to proactive, and from rigid to intelligent.

Collaboration, policy, and education will define the next industrial era

The transition, however, cannot rely on technology alone. It requires coordination across the ecosystem. No single company can build the infrastructure for advanced manufacturing at scale. Collaboration between operators, suppliers, certifiers, and universities is essential. Shared investment in regional hubs, joint facilities, and standardized digital libraries would create steady demand and common benchmarks. These partnerships would also nurture the skilled workforce needed to operate new tools, bridging the talent gap that often holds back innovation.

Policy support will play a decisive role. While government mandates can stifle progress, incentives can accelerate it. Tax credits, innovation grants, and procurement preferences for locally manufactured or low-carbon components could give industries the confidence to invest. Policy should reward early adopters rather than penalize laggards, fostering a culture of experimentation that turns pilot projects into permanent capabilities.

Sustainability is another powerful argument. Additive manufacturing uses only the material required for each part, reducing waste and emissions. It eliminates the need to ship bulky equipment across continents, cutting transportation-related carbon output. This efficiency aligns directly with national climate goals and corporate decarbonization strategies. The process itself, requiring less heat and energy than conventional fabrication, offers a lower-carbon footprint. The result is a manufacturing method that is not only faster and cheaper but cleaner.

Still, even as technology evolves, perception must catch up. Many buyers remain focused on cost rather than value, preferring familiar methods that seem cheaper upfront but cost more over time through delays, waste, and inefficiency. Shifting this mindset requires consistent communication. Companies must demonstrate that advanced

manufacturing is not an experiment but a necessity—and that investing in it secures both profit and resilience.

Education will be vital to sustaining momentum. Universities and research centers, such as Khalifa University in the UAE, are already training the next generation of engineers and technicians in 3D printing, robotics, and digital design. These institutions bridge the gap between innovation and industry, ensuring that knowledge flows quickly from laboratory to factory floor. Without this human foundation, even the best technology will stall.

The conversation about waste also highlights another opportunity. Around the world, warehouses and industrial yards are filled with surplus materials and unused parts. Instead of discarding them, industries can build global catalogs for reuse and resale. Developing markets or smaller operators could acquire these components at lower costs, keeping them in circulation and extending their life cycle. The circular economy is not only about recycling materials; it is about rethinking how and when things are produced in the first place.

The urgency to act is clear. Industries that fail to scale advanced manufacturing will face increasing inefficiency, vulnerability, and competitive decline. Those that embrace it will gain agility, sustainability, and strategic independence. The technology has matured, the standards are forming, and the business models are emerging. What remains is the collective will to act decisively. Waiting for the perfect standard or policy will only delay progress. The better path is collaborative experimentation—learning by doing and improving along the way. The next industrial era will not be defined by who has the largest factories but by who can adapt the fastest. ■

SOUNDINGS

"Across the industry, we're hearing a consistent message — OEMs are under pressure to bring projects online faster and more cost-effectively, and additive manufacturing enables that by producing at scale and speed. For end users, the value lies in reducing inventory and responding rapidly with spare parts. Two different challenges, one transformative solution."

Nick Evans, Sales Director, DEEP Manufacturing

"We're heading toward an oilfield services supply chain bottleneck as exploration activity inevitably ramps up to address looming oil supply shortages and energy security concerns over the next decade. To prevent this, manufacturing must scale beyond pilot projects and into full industrial deployment."

Amr Wahby Mahmoud, Vice President – Middle East and North Africa Supply Chain Research, Rystad

"We took over legacy infrastructure from Shell — it's vast and with significant brownfield scope. Additive manufacturing offers us a great opportunity: the ability to repair, replicate, and replace legacy parts without starting from scratch."

Abdulrahman Mijinyawa, Chief Technical Officer, Renaissance Africa Energy Company Limited

"Refiners are conservative. The fear of corrosion and downtime makes them cautious to adopt new parts. But the difference between Asia and the Middle East is closing — everyone wants to catch up to world-leading standards."

Michael Boo, General Manager, GS Caltex Abu Dhabi

"Additive manufacturing is already starting to be adopted across many sectors, for example energy and maritime. The next evolution we foresee is digital warehousing — maintaining a certified digital inventory of critical spare parts so they can be printed on demand in any location, and under a globally aligned scheme of requirements like DNV-RP-B205."

Jan Zschommler, Market Area Manager Middle East & Africa, DNV

"AI-driven analysis shows that up to 70% of emergency spare parts in warehouses have never been used. Combining AI with 3D printing could cut costs 40%, if companies shift from stockpiling to manufacturing on demand."

Dr. Satyam Priyadarshy, Chief Executive Officer, ReigniteFuture

"Technology is evolving faster than our ability to manage the waste it creates. We're creating stockpiles of obsolete parts with no plan for reuse. We need global catalogs to repurpose surplus materials — circular economy thinking must accompany innovation."

Anita Nouri, Chief Executive Officer, Green Growth Consultancy LLC

"Standardization is the accelerator. We must develop standards in real time with industry participation — not in isolation. Collaboration among manufacturers, regulators, and end users is critical for credibility and speed."

Nahla Abid- Gribaa
Vice President Southern Middle East
Bureau Veritas

"Additive manufacturing shouldn't replace traditional methods — it should complement them. Decentralized production hubs with skilled operators are key to solving supply chain disruption sustainably."

Dr. Bashar El-Khasawneh, Professor of Practice, Mechanical & Nuclear Engineering Khalifa University

TOP 20 TAKEAWAYS

1. Moving Beyond Pilot Projects

Advanced manufacturing must move from pilot concepts to industrial-scale deployment to strengthen supply chain resilience. Delays in adoption risk perpetuating vulnerabilities seen during recent global disruptions. The sector's competitiveness now depends on scaling technologies that cut lead times, enhance responsiveness, and sustain production continuity across global and regional markets.

2. Deployment as Core Mission

Deep Manufacturing exemplifies practical commitment by deploying advanced technologies rather than remaining theoretical. The company's subsea habitat project demonstrates real-world implementation of additive manufacturing to produce large-scale, certified pressure vessels, proving that advanced manufacturing can meet both research and commercial standards while reducing traditional build timelines by more than half.

3. Additive Manufacturing's Speed Advantage

Additive manufacturing significantly shortens lead times compared to traditional fabrication. Projects previously requiring ten months can be completed in five, allowing industries like oil and gas to react faster to market or operational needs. Speed and scalability make additive processes a key strategy for achieving just-in-time production capabilities globally.

4. Certified Industrial Standards

Certification remains central to industry confidence. Achieving DNV qualification for human-rated pressure vessels validates additive manufacturing's industrial readiness. Third-party verification ensures quality, safety, and repeatability—crucial factors for persuading conservative sectors such as oil and gas and refining to trust new manufacturing technologies in mission-critical applications.

5. Industry Adoption Gaps

Aerospace leads in adopting additive manufacturing, driven by acute supply chain pressures and mission-critical needs. Oil and gas remain cautious, citing reliability and downtime concerns. The difference lies in cultural readiness to embrace innovation rather than technical limitations. Accelerating adoption demands mindset change supported by cross-sector collaboration and standardization.

6. Supply Chain Vulnerabilities

Future supply bottlenecks are expected as demand grows in both traditional hydrocarbons and low-carbon sectors. Without scaling advanced manufacturing, industries risk energy insecurity and delayed projects. Leaner, faster production models are necessary to avoid shortages and ensure efficient deployment of components and systems in complex global operations.

7. Balancing Inventory and Cost

Companies face a double challenge: maintaining sufficient inventory for resilience while avoiding excessive stockpiling that inflates costs. Additive manufacturing enables a middle ground by producing spare parts on demand, minimizing waste and capital tied in unused components while maintaining flexibility against global supply disruptions.

8. Upstream Modernization Needs

Brownfield operations, especially in Africa, face aging infrastructure and out-of-certification equipment. Additive manufacturing offers a lifeline by enabling local fabrication of replacement parts without rebuilding new facilities. This approach supports production continuity and helps operators achieve ambitious output expansion targets efficiently and affordably.

9. Cultural Resistance to Change

Large international companies often delay adoption because they can afford redundancy and backup capacity. Smaller independents, under performance pressure, move faster. Real transformation requires breaking this comfort cycle through policy incentives, industry partnerships, and visible success stories demonstrating that first movers gain measurable efficiency and resilience benefits.

10. Regional Perspectives

Asian and Middle Eastern refiners share a conservative approach to new technologies, prioritizing operational stability over innovation. However, regional differences show progress: the Middle East is catching up to global leaders, adopting international best practices, while East Asia leverages decades of experience to modernize legacy infrastructure.

11. Standardization as Enabler

Harmonizing certification standards across organizations such as DNV, API, and ASME is essential. Current overlaps—often exceeding 80% equivalency—create duplication and delay. Unified frameworks would accelerate qualification, reduce costs, and encourage faster technology integration, allowing manufacturers to meet multiple industry requirements through a single certification process.

12. Digital Warehousing Evolution

The industry is transitioning toward digital inventories of spare parts, or "digital passports." These standardized files allow certified manufacturers worldwide to print approved components on demand. This model replaces vast physical warehouses with cloud-based databases, enhancing flexibility, reducing logistics costs, and enabling global interoperability between suppliers.

13. AI's Transformative Role

Artificial intelligence can optimize additive manufacturing by predicting demand, reducing overproduction, and improving accuracy. Integrating AI with digital inventories allows predictive maintenance and smarter material allocation, cutting waste and costs. Data-driven insights enhance responsiveness to disruptions while building a more intelligent, agile manufacturing ecosystem.

14. The Case for Hybrid Manufacturing

Combining traditional techniques with additive processes offers a balanced approach. Hybrid systems leverage existing CNC, casting, and forging capabilities while using additive layers for complex geometries or bottleneck components. This pragmatic pathway minimizes risk, maximizes compatibility, and accelerates industrial acceptance of advanced manufacturing.

15. Building Collaborative Ecosystems

No single company can establish advanced manufacturing at scale. Industry-wide collaboration—linking operators, manufacturers, certifiers, and research institutions—is required. Shared investment, joint facilities, and standard digital libraries can ensure steady demand and reduce entry barriers, allowing regional manufacturing ecosystems to thrive sustainably.

16. Policy and Incentive Gaps

Regulatory frameworks have not kept pace with technological progress. Governments could accelerate adoption through incentives, tax relief, and procurement policies that reward innovation. Policy support—rather than mandates—can build confidence among hesitant industries and align manufacturing goals with national sustainability and industrial strategies.

17. Waste Reduction and Circularity

Additive manufacturing's precision reduces material waste by producing only what is needed. It supports a circular economy where unused inventory can be repurposed, recycled, or digitally catalogued for resale. This sustainability angle, often overlooked, strengthens the environmental case for scaling advanced manufacturing globally.

18. Education and Skills Development

Human expertise is as vital as technological innovation. Developing skilled operators, engineers, and inspectors capable of managing new manufacturing tools is critical. Collaboration between universities, certification bodies, and industry ensures a talent pipeline equipped to sustain advanced manufacturing growth long-term.

19. Market Readiness and Buyer Mindset

Technological capability means little without market willingness. Buyers often prioritize cost over innovation, discouraging investment in new technologies. True progress requires aligning procurement criteria with performance, sustainability, and lifecycle value rather than short-term price considerations, ensuring innovation receives both recognition and reward.

20. The Urgency of Action

Failure to move beyond pilot programs risks stagnation, inefficiency, and economic loss. Advanced manufacturing is no longer experimental—it is essential. To stay competitive, industries must commit to full-scale deployment, unified standards, and shared learning. Collaboration, certification reform, and sustained investment will define the future of industrial resilience. ■

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www.deepmanufacturing.com

dml@deep.com