Topic-2

Additive Manufacturing in the Energy Industry

Beyond the Buzzword: Grounded Insights on Digitalization in Energy Series

Additive manufacturing (AM), often referred to as 3D printing, is a transformative technology that builds objects layer by layer from digital designs. Unlike traditional subtractive methods that cut away material, AM creates parts directly from raw materials such as metals, polymers, or composites. This allows for unprecedented design freedom, customization, and rapid production cycles. In the energy industry, AM is increasingly being adopted to improve operational performance, particularly in the oil, gas, and renewable sectors.

Enhancing Efficiency

AM enables the production of complex, high-performance components with minimal waste and shorter lead times. In oil and gas, this has led to optimized designs for downhole tools and heat exchangers. In renewables, it supports lightweight, aerodynamic parts for wind and solar systems, streamlining both design and deployment.

Reducing Costs

By enabling on-site or near-site production, AM reduces the need for extensive inventory and long-distance shipping—critical for operations in remote areas. Companies like GE, Shell and Siemens Energy have leveraged AM to replace hard-to-source parts quickly, cutting down on downtime and supply chain costs.

Improving Safety

3D printing reduces the reliance on welds and joints, often the weak points in traditional assemblies. This minimizes failure risks. Additionally, the ability to rapidly prototype and test new components supports safer, more reliable system designs.

Limitations and Considerations

Despite its benefits, 3D printing is not suitable for all scenarios. Large structural components like pipelines or pressure vessels are often better suited to traditional manufacturing methods. Material limitations, regulatory hurdles, and cost considerations still restrict the use of AM in high-stress environments.

Discover how cutting-edge additive manufacturing is powering innovation in the energy sector—streamlining design, reducing downtime, and accelerating delivery with digital precision.

Comparison of Additive 3D Printing Techniques

Tech	Materials	Production Rate	Part Size	Part Quality	Post-Processing
Powder Bed Fusion (SLM, DMLS, EBM)	Metals	M	S-M	H	HT, MC
Directed Energy Deposition (DED, WAAM)	Metals	H	LA	MO-H	HT,MC
Binder Jetting	Metals, sand	H	M-LA	MO	SI,IN
Material Extrusion (FDM, FFF)	Thermo plastics	M-H	S-LA	L-MO	MC
Vat Photopolymerization (SLA, DLP)	Photo polymers	M	S-M	VH	Curing
Sheet Lamination	Paper, foil	M-H	M-LA	MO	TR
Selective Laser Sintering (SLS)	Nylon, TPU	M	S-M	MO-H	DP
Continuous Fiber Reinforcement (CFR)	Thermo plastics + fibers	M	S-M	H	L

Index: H=High, M=Medium, S=Small, HT=Heat treatment, MC=Machining, LA=Large, L=Low, MO=Moderate, SI=Sintering, IN=Infiltration, DP=De-powdering, TR=Trimming

Typical Applications in the Energy Sector

Sector	Applications
Gas turbines	Combustion nozzles, heat shields, fuel injectors
Oil & Gas	Downhole tools, valves, impellers, manifolds, part repair
Wind energy	Blade brackets, sensor housing, aerodynamic prototypes
Solar energy	Structural frames, concentrator components, mounts
Nuclear	Pump components, shielding parts, non-critical fixtures

Where 3D Printing Works — and Where It Does not

Suitable For	Generally Not Recommended For
Low-volume, complex parts	High-volume production
Legacy part replication	Large structural parts
Internal geometries and lattice structures	Parts under high cyclic loading (currently)
Rapid prototyping	Simple shapes that are cheaper to cast or forge

Typical Economics: 3D Printing vs Casting and Forging

Aspect	3D Printing	Casting	Forging
Tooling Cost	None	High	High
Lead Time	Short	Long	Long
Per Part Cost (Low Volume)	Moderate	High	High
Per Part Cost (High Volume)	High	Low	Low
Design Flexibility	High	Low	Low
Complexity Handling	Excellent	Moderate	Low

Why 3D Print When Casting and Forging Are Available?

Advantages of 3D Printing	**Limitations of Casting/Forging**
Rapid prototyping	Slow tooling changes
Complex geometries	Design constraints
On-demand production	Requires inventory
Lightweight structures	Material-heavy processes
Legacy part production	No tooling available for obsolete parts

Additional Challenges of 3D Printing

Limited material selection and variable feedstock quality
Extensive post-processing requirements
Certification and regulatory hurdles
Build size limitations
High equipment and operational costs
Need for specialized design and process engineering skills

Digitalization for Value Engineering and Productivity in the AM Value Chain

Digitalization is reshaping additive manufacturing (AM) with smart, connected workflows from design to production. AI-driven design tools, digital twins, and real-time simulation enable faster, optimized part development with built-in performance insights.

On the shop floor, IoT sensors and integrated MES systems ensure traceable, high-quality builds with in-situ monitoring and control. Digital supply chains enable on-demand, distributed manufacturing—cutting lead times, reducing waste, and boosting agility.

For energy and other high-performance sectors, this means smarter value engineering, faster time-to-market, and a decisive edge in operational efficiency.

What techniques/manufacturing process to use.

It is often a function of thee drivers-part size, urgency, efficiency, cost, availability, and geography.

Tech	**Materials**	**Apps.**
Powder Bed Fusion (SLM, DMLS, EBM)	Metals	Turbines, downhole tools
Directed Energy Deposition (DED, WAAM)	Metals	Repair, large structures
Binder Jetting	Metals, sand	Casting molds, spare parts
Material Extrusion (FDM, FFF)	Thermoplastics	Prototypes, jigs
Vat Photopolymerization (SLA, DLP)	Photopolymers	Molds, models
Sheet Lamination	Paper, foil	Prototyping
Selective Laser Sintering (SLS)	Nylon, TPU	Ducts, functional parts
Continuous Fiber Reinforcement (CFR)	Thermoplastics + fibers	Brackets, tooling

Potential and Future Applications of Additive Manufacturing in the Energy Sector

Sector	Potential Applications
Oil & Gas	On-site emergency repair systems, smart valve components
Gas Turbines	Integrated sensor-embedded blades, in-situ AM maintenance
Wind Energy	Full-size custom blade sections, in-field AM repair units
Solar Energy	High-efficiency heat exchanger structures, advanced concentrator designs
Hydrogen & Fuel Cells	Porous transport layers, optimized flow field plates

Hybrid Manufacturing in the Additive Realm (Topic-3 to follow)

Hybrid manufacturing combines additive manufacturing (AM) with subtractive techniques like milling or turning in a single setup or workflow. This integration allows manufacturers to take advantage of the design freedom and material efficiency of AM, while also achieving the precision, surface finish, and tolerances of traditional machining. In the energy sector, hybrid manufacturing is especially beneficial for producing and repairing high-performance components such as turbine blades, impellers, and pump parts where both intricate geometry and tight tolerances are required. It also enhances the value of castings and forgings by enabling post-processing, precision features, or localized repairs, reducing scrap and improving component performance and service life.