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Closing the Loop: A Techno–Economic Perspective on Circular Manufacturing and Green Hydrogen in Bangladesh

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Abstract

Circular manufacturing offers a pathway to reduce waste, conserve resources, and improve environmental sustainability, but its practical value depends on technical and economic feasibility. This research blog examines the intersection of circular economy practices and techno-economic analysis in Bangladesh, with green hydrogen considered as a potential low-carbon pathway for future manufacturing systems. Existing research shows growing interest in circular production, resource recovery, and sustainable hydrogen, yet these areas are often assessed separately. The blog argues that environmental benefits should be examined alongside investment costs, energy demand, technological readiness, resource recovery, and social outcomes. An integrated approach can support circular manufacturing pathways that are environmentally meaningful, economically realistic, and socially responsible.

Keywords: *Circular economy; techno-economic analysis; circular manufacturing; green hydrogen; environmental sustainability*

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Rationale

What makes a manufacturing system truly circular? Recycling waste is one part of the answer. Reusing materials and extending their useful life are also important. Yet circularity cannot be understood only by looking at what happens to waste after production. It must also consider where materials come from, how energy is used, how products are designed, and whether resources can remain within the production system for longer.

This question is particularly important for Bangladesh. Manufacturing supports employment, exports, industrial growth, and national development. At the same time, industrial activities consume large amounts of energy, water, and raw materials. They also generate waste and environmental pressure. Circular economy thinking offers an alternative to the traditional pattern of taking resources, producing goods, and discarding what remains. It encourages industries to reduce waste, recover materials, reuse resources, and create value from what was previously treated as a burden (Azizuddin et al., 2021).

The logic follows the purpose of a research rationale, where the importance and context of a problem should be established before presenting the main argument (Hasan et al., 2026). For circular manufacturing, the central issue is not simply whether a resource can be recovered. A more difficult question must be asked. Is the proposed circular process technically workable, economically affordable, and environmentally beneficial?

This is where techno-economic analysis becomes important. A recycling technology may recover valuable material but require expensive machinery. A waste conversion system may reduce landfill pressure but consume significant energy. A new production process may reduce emissions while increasing operating costs. Environmental benefits therefore need to be considered alongside capital investment, operating expenses, energy demand, technological performance, and potential economic return (Aretoulaki et al., 2026).

Green hydrogen introduces another possibility. It may support cleaner industrial production where direct electrification is difficult. It may also become connected with circular systems when renewable electricity, recovered water, biomass residues, or organic waste contribute to hydrogen production. Research in Bangladesh has already explored sustainable hydrogen pathways and the economic and environmental conditions that may influence their development (Wasima et al., 2025; Islam et al., 2026).

However, green hydrogen also reminds us that sustainability has a social dimension. Research from Australia shows that hydrogen development can influence employment, regional opportunities, public acceptance, and perceptions of fairness. These issues may differ across countries, but they show that a technological transition cannot be judged only by cost and emissions. People must also understand how the benefits and risks are distributed (Kalam et al., 2026).

Research Gap

The research gap lies in the limited integration of circular economy thinking, techno-economic analysis, environmental sustainability, and emerging clean technologies within the manufacturing context of Bangladesh. The problem is not that these subjects have received no attention. Research already exists on circular economy development, industrial readiness, resource recovery, waste management, and hydrogen production. The deeper issue is that these areas are often examined separately.

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A research gap should identify what remains unresolved and explain why that missing knowledge matters (Hasnat et al., 2026). In Bangladesh, circular practices may be evaluated through waste reduction or recycling performance. Hydrogen projects may be assessed through production cost or technical efficiency. Environmental studies may focus on emissions or resource consumption. Each approach provides useful information, but none alone can show whether a new circular manufacturing pathway will work as a complete system.

This creates an important problem. A factory may increase recycling and report lower waste. Yet the new recycling process may require additional electricity, water, chemicals, transportation, or imported equipment. The environmental burden may therefore move from one part of the system to another. Without a combined assessment, a practice may appear circular while creating new economic or environmental pressures.

The same issue applies to green hydrogen. Hydrogen produced from renewable electricity may reduce carbon emissions in some industrial applications. However, its feasibility depends on electricity cost, electrolyzer technology, water availability, storage, infrastructure, financing, and plant utilization. It should therefore not be treated as automatically sustainable simply because it is described as green. Its complete production and use pathway must be examined.

Another gap concerns the social side of technological transition. Circular manufacturing and green hydrogen may create new jobs and industrial opportunities, but they may also require new skills and investment. Benefits may not reach every region or community equally. Public understanding and trust may also influence how new technologies are accepted. Kalam et al. (2026) show that employment, regional fairness, stakeholder engagement, and public acceptance are important parts of green hydrogen development. Similar questions remain underexplored in Bangladesh.

The real research need is therefore more integrated evidence. Bangladesh needs frameworks that examine material flows, environmental effects, technical performance, economic feasibility, and social outcomes together. Such an approach could help identify which circular manufacturing strategies create genuine value under local conditions.

Future Implications

Future progress should begin by connecting circular ambition with measurable evidence. Policies and company strategies may encourage industries to become more circular. However, good intentions cannot show whether a particular technology will work economically and environmentally in a real factory. Future implications should therefore connect existing evidence with practical directions for policy, industry, and innovation (Khandakar et al., 2026).

Future research should combine techno-economic analysis with environmental assessment. Capital costs, operating costs, energy requirements, material recovery, emissions, water use, equipment lifetime, and market value should be examined within the same framework. This would help researchers identify whether a circular solution reduces environmental pressure without creating an unreasonable economic burden.

Different manufacturing sectors should also be examined separately. Textile industries may focus on fibre recovery and material reuse. Food-processing industries may find value in organic waste conversion. Metal industries may benefit from remanufacturing and material recovery. One circular strategy cannot work equally well across every sector.

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Green hydrogen should be assessed in the same careful way. Its strongest role may be in industries where direct electrification is difficult or where hydrogen is already used as an industrial input. Bangladesh should begin with carefully selected pilot projects rather than assuming that large-scale deployment will automatically be successful. These projects should generate transparent information about cost, energy use, water requirements, emissions, technical performance, and operational challenges.

The social dimension should also become part of future assessment. Workers may require new skills. Communities may have concerns about safety, land, water, or access to project benefits. Clear communication and early stakeholder engagement can help build trust. Lessons from Kalam et al. (2026) suggest that technological transitions are more likely to gain support when communities can see local value and feel that benefits are distributed fairly.

The future of circular manufacturing therefore depends on more than closing material loops. It requires understanding what happens when those loops are closed. A process that saves waste but consumes excessive energy may not be the best solution. A technology that reduces emissions but cannot survive economically may struggle to continue. A project that creates environmental benefits but leaves local communities behind may also face resistance.

The real opportunity lies in bringing these perspectives together. Circular economy thinking can show where resources should remain in use. Environmental assessment can show whether ecological pressure is actually reduced. Techno-economic analysis can show whether the proposed system can work under real industrial conditions. Social assessment can show who benefits and who may carry the risks.

For Bangladesh, the central question is therefore not simply how manufacturing can become more circular. It is how circular manufacturing can become technically workable, economically realistic, environmentally meaningful, and socially fair. Green hydrogen may become one part of this transition. Its role, however, should be guided by evidence rather than expectation. Bringing these disciplines together can help move circular economy thinking from ambition toward practical and responsible industrial transformation.

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Conflict of Interests
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