# THE SUSTAINABLE MANUFACTURING REVOLUTION

## Why the circular economy has the potential to transform manufacturing in low-income countries

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# CONTENTS

# FOREWORD

## The sustainable manufacturing revolution

There's a school of thought that the inevitable price of economic development is pollution and human suffering. Some believe the drive for a competitive manufacturing base can only succeed with little concern for the environment or people's standard of living. It's certainly what's happened in the past – and what's happening in today's low-income countries.

But it doesn't need to be that way. Economic development can build a positive human future.

In this report, you'll read about industries damaging the environment and putting lives at risk, such as Bangladeshi tanneries that empty 220,000 cubic metres of hazardous waste into local rivers every day.

Overcoming a challenge of this scale will take ingenuity. It will take diverse teams from across the public and private sectors to transfer the experience of the developed world to build a circular economy. By finding innovative ways to re-use, recycle and refurbish throughout the manufacturing process, it will be possible to build a positive human future in our technology-driven world.

Using this approach, this report recommends a range of ways for cleaning up four industries in the developing world: textiles, tanneries, food processing and chemical manufacturing. For example, mobile effluent-treatment plants could drastically cut the hazardous waste reaching the river from those Bangladesh tanneries.

Legislation can ensure the pressure to be competitive doesn't trump the rights of employees and people who live near factories and industrial plants. So, we've explored what governments can do to make it easier for businesses to do the right thing. And our message for global brands? Embrace the circular economy at every point in your supply chains.

There's an ambitious programme to put the recommendations into practice. And the partnership between PA Consulting and the UK Department for International Development reflects the shared responsibility to act. That's why this report is also a call for governments, businesses and those working in international development to collaborate more and make the most of these opportunities.

We believe it's possible to turn traditional thinking about the cost of economic development on its head. The circular economy can create sustainable industries and produce shared prosperity – that's a positive human future we can all strive towards.

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# INTRODUCTION

At a time of growing awareness about sustainability, manufacturing processes are coming under the microscope. The scrutiny is particularly intense in the developing world. More manufacturing is increasingly being concentrated in developing countries, negatively impacting on people and the environment.

On the flip side, successful manufacturing processes can play a significant role in transforming a country's economy. We've seen this in Southeast Asia, where a spectacular rise in new manufacturing hubs has significantly improved living standards and economic prosperity within one generation. For example, Vietnam has transformed itself from a low-income country with a small agricultural economy, to a successful exporter of a wide range of manufactured goods.

The good news is, we're witnessing a similar transformation take place in low-income countries today. Examples include the economic growth from textile and tannery industries in Bangladesh, the agro-processing sector in Kenya and chemical manufacturing in Nigeria. These examples show how parts of Asia and sub-Saharan Africa are benefiting from industrial strategies, with increased production, higher employment and more trade and investment.

Manufacturing will continue to play a pivotal role in growing the economies of low-income countries. However, this growth is coming at an unsustainable cost. The monetary cost of waste is rising, and many traditional manufacturing approaches damage the environment and people's health.

More value can be unlocked by taking an alternative approach. The circular economy (CE) is a restorative and regenerative system that minimises resource input and waste. By using strategies and disruptive technologies that reduce environmental impact while creating economic value, low-income countries can transform the manufacturing industry to be cleaner, safer and economically beneficial.

Applying CE principles to manufacturing also has the potential to get us closer to achieving the United Nations Sustainable Development Goals (SDGs), a set of 17 goals to help countries achieve a more sustainable future.

In this report, we explore some of the emerging CE strategies and trends low-income countries can embrace. We're seeing new technologies and processes being used by organisations adopting CE approaches in the developed world and significant opportunities for low-income countries to revolutionise their manufacturing by applying best practice. Possible methods include substituting or removing specific inputs, improving process efficiency, and capturing, treating or 'looping' waste emissions. All these practices can limit the harm of manufacturing methods and create new business opportunities. Besides, establishing a support system that encourages circular waste innovation from the bottom-up must be implemented in parallel with top-down approaches.

> The CE approach reduces barriers and provides a coordinated effort to kick-start activity.

But the widespread adoption of the CE in manufacturing will not be easy. Governments, international donors and the private sector can play a pivotal role by introducing environmentally friendly manufacturing legislation, building in-country CE capability and delivering flagship initiatives that demonstrate economic and environmental benefit. Support with transition costs and further research will also be vital.

The CE approach provides a significant opportunity for low-income countries to further their development, achieve growth, prevent ecological damage and improve their populations' living standards.

The four areas low-income countries should focus on are:

- **overcoming the barriers of the circular economy** – building technical capability, identifying finance solutions and whole system modelling to assess the implications of actions taken.
- **defining new roles for government, donors and private sector** – building knowledge and capability, leading by example and developing and implementing legislation to encourage positive, circular and sustainable behaviours.
- **adopting innovative new business models** – looking across the whole value chain at the opportunities that exist, including extracting new value from by-products and flexible manufacturing approaches.
- **encouraging emergent circularity** – embedding a support system to help bottom-up circular entrepreneurial activities in regions with industrial waste streams but limited access to the knowledge and technology.

# 1 WHAT IS THE CIRCULAR ECONOMY?

Today's economy is primarily linear. It follows a 'take, make, use and dispose' model, relying on large quantities of cheap, easily accessible materials and energy.

The ultimate ambition of the CE is to be restorative and regenerative by design, and aims to keep products, components and materials at their highest utility and value at all times.

# Involving the entire value-chain

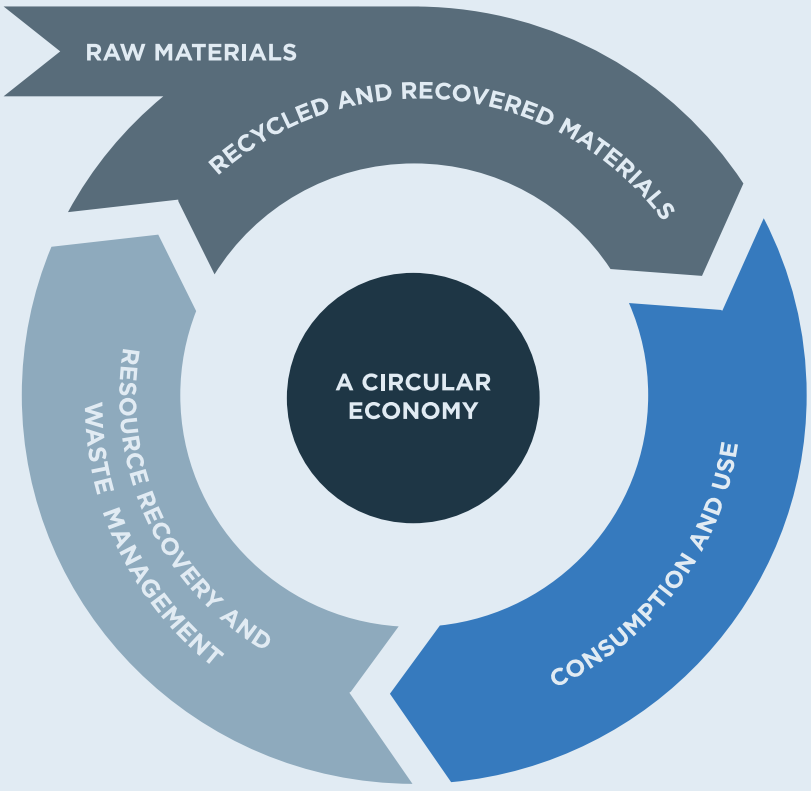
**Embracing the CE entails focusing the entire product value-chain on:**

- reusing, refurbishing and recycling
- maximising inherent value in products and by-products
- reducing material and energy costs
- consuming services rather than purchasing assets.

Figure 1 shows how the CE reduces the dependence on raw materials. This means value is retained and waste is minimised.

Take the production of a simple cotton T-shirt as an example. The traditional manufacturing process would involve farming the cotton, making the T-shirt,[1] selling and using it, and disposing of any waste into landfill or water networks. It's estimated that approximately 70 per cent of the climate impact from T-shirt production comes from the manufacturing stage. In comparison, a CE approach would see the waste in the manufacturing process and its associated value recovered and used for the highest value application. It could also extend to changing manufacturing processes so that they could receive end of life T-shirts as a by-product. It's estimated that only nine per cent of the current global economy uses CE models. However, this number is expected to increase.[2]

Figure 1 – HOW THE CIRCULAR ECONOMY REDUCES THE DEPENDENCE ON RAW MATERIALS



# 2 THE ENVIRONMENTAL IMPACT OF MANUFACTURING IN LOW-INCOME COUNTRIES

The success of manufacturing, and the development potential of low-income countries, are under threat. Many of these countries' economic competitiveness has been built on their wealth of natural resources and the low cost of labour and processing (which in part is driven by less stringent regulation of the environmental impact and waste they produce). The global appetite for these finite resources continues to grow, which means there has never been a greater need for the manufacturing sector to waste less and use resources more efficiently whilst adopting business models that reward strong environmental and waste stewardship. The monetary cost of waste is rising, while traditional manufacturing approaches cause environmental damage and negatively affect people's health.

Here, we focus on five of the largest manufacturing industries in low-income countries: textiles, tanneries, food processing and chemical manufacturing. And we also look at packaging pollution, an issue that spans these industries and many others.

## Textiles

The textile industry often lies at the heart of economic and industrial strategies in low-income countries. But the industry in its current form is energy intensive and produces high-levels of air and water pollution. The industry uses more than 8,000 chemicals to make the 400 billion square metres of fabric sold annually around the world. The majority of chemicals are toxic and remain in the environment for long periods. And it's water-intensive – producing a pair of jeans requires approximately 1,800 gallons of water.[3]

CASE STUDY

**The negative health and social consequences of Dhaka's textile industry**

Textile production is one of Bangladesh's most important industries. In the area around Dhaka, the capital, there are hundreds of factories carrying out washing, dyeing and finishing activities. The International Finance Corporation suggest this area generates 200 metric tonnes of wastewater per tonne of fabric, as well as significant air pollution. As a country that is already environmentally fragile and vulnerable to natural disasters, such as large-scale flooding, increased pollution in coming years could have devastating consequences.[4]

## Leather tanning

Leather tanning is the process of converting raw animal hides or skins into leather for consumer products. There are two main methods of tanning: chrome tanning and vegetable tanning. Chrome tanning is more prevalent than vegetable tanning and accounts for 90 per cent of global leather production.[5] The process involves soaking the leather in a solution containing chemical agents. The Pure Earth Toxic Sites Identification Program, established by the Blacksmith Institute, aims to identify and screen contaminated sites in low- and middle-income countries where public health is at risk. The programme identified more than 100 sites polluted by tannery operations, which put around 1.5 million people at risk.[6]

CASE STUDY

**The environmental and human hazards of the tanning industry in Bangladesh**

The Hazaribagh neighbourhood, in the heart of Bangladesh's capital, is home to 95 per cent of the country's tanneries and one of the most intensely polluted places on the planet. The industry has a terminal impact on the surrounding environment; 220,000 cubic metres of waste containing 40 heavy metals flows into the Buriganga River daily. The effluent discharge was found to include chromium, sulphuric acid, formic acid, caustic soda, caustic potash, soda ash, sodium arsenite and arsenic sulphite, and much of the discharge is black in colour.[7]

> The textile industry uses more than 8,000 chemicals to make the 400 billion $m^2$ of fabric sold annually around the world.

## Food-processing

The agro-processing industry refers to manufacturing processes that transform raw materials and intermediates from the agricultural sector to an end, consumable form. Agriculture and agro-processing are vital to low-income countries, particularly in sub-Saharan Africa and Asia, with their tracts of fertile land. The industry brings a number of damaging side effects, including the discharge of waste into the water supply and the emission of dust or gases that can have negative impacts on ecosystems and human health.

CASE STUDY

**The impact on liquid waste from food processing industries in Nigeria**

Nigeria's food processing industry alone is valued at $10 billion, providing 10 million direct jobs.[8] But the growth of this industry has also had adverse impacts on the surrounding environment.

A 2008 study analysed the liquid waste emanating from two food processing centres in Lagos and Jos. Findings showed that the organic parameters of the liquid waste sites far exceeded the maximum allowable levels by the Nigerian Federal Environmental Protection Agency (FEPA).[9] We believe this is probably a very common situation in low-income countries.

## Chemical manufacturing

Chemical manufacturing includes plastics, paints, explosives, dyes, pharmaceuticals, petrochemicals and more. It's in the top 10 most polluting industries in the world, yet is integral to modern life - more than 70,000 products emanate from the industry globally.[10] However, it's estimated the industry is putting approximately 5.3 million people at risk of exposure to pollution.[11]

> Since the 1950s, some 8.3 billion tonnes of plastic have been produced worldwide.

CASE STUDY

**South Durban's petrochemical pollution**

South Africa's petrochemicals industry is a vital cornerstone of the national economy and South Durban is the country's hub for petrochemical manufacturing. Despite the jobs and opportunities this industry has brought, it has a devastating impact on the environment and human health. Cancer rates in South Durban are at crisis level - leukemia prevalence is 24 times higher that anywhere else in the country, and the area is known as cancer valley. Over 100 chemicals are pumped into the air, including sulphur dioxide and benzene, which the World Health Organisation (WHO) suggest are closely linked to asthma, cardiopulmonary disease and cancer.[12]

## Packaging pollution

Since the 1950s, we've produced 8.3 billion tons of plastic worldwide. And to date, we've only recycled around 9% of this.[13] When we think of this problem, we usually focus on the single-use packaging that comes with final products, but there's a significant amount of plastic waste created during manufacturing. This ranges from the packaging used to hold together the raw materials entering the factory (e.g. corrugated card, cellophane wraps on pallets, plastic bands) through to the actual containers these raw materials arrive in (e.g. plastic bags, single use chemical containers) and the bulk packaging that holds together the final outputs, and the boxes and pallets they're shipped in.

CASE STUDY

**Mismanaged plastic waste from low-income countries**

The Chartered Institute of Waste Managers and the UK-based NGO WasteAid claims that mismanaged waste from low-income countries accounts for up to 70 per cent of ocean plastic by weight.[14] And just five countries in East Asia are responsible for most of this. Meanwhile 38 out of 50 of the world's largest uncontrolled dump sites are in coastal areas and many of them spill waste directly into the sea.

**In South Durban (...) Over 100 chemicals are pumped into the air, including sulphur dioxide and benzene, which the WHO suggests are closely linked to asthma, cardiopulmonary disease and cancer.**

3

# THE THREE KEY STEPS TO THE CIRCULAR ECONOMY

As high-income countries increasingly implement CE practices in their manufacturing, low-income countries have the opportunity to benefit from learnings to exploit huge development opportunities. In this chapter, we explore the technologies and processes low-income countries can take advantage of to reduce manufacturing waste, and keep it in the value chain.

We believe that applying aspects of the CE to manufacturing can have a significant impact on environmental emissions. The focus should be on three key areas:

- Substituting and removing harmful inputs
- Improving process efficiency
- Developing by-product capture and treatment.

In each area, it's possible to identify a number of process improvements and technologies that have the potential to transform manufacturing in low-income countries.

# Substituting and removing harmful inputs

## Substituting

Substituting looks for ways to replace materials used in production, either aspects of them or the whole material, to mitigate harmful environmental effects. An example of substitution is in the paint industry, where water-based paints are now far more common than their solvent-based predecessors.

Eco-friendly biocides, used in industrial cleaning, are another exciting – and growing – area of substitution. Biocides are substances that destroy harmful organisms, such as viruses or bacteria. And eco-friendly biocides rapidly break down into water and oxygen. This means they have no toxic effect in their diluted state, and no carcinogenic or mutagenic effect.

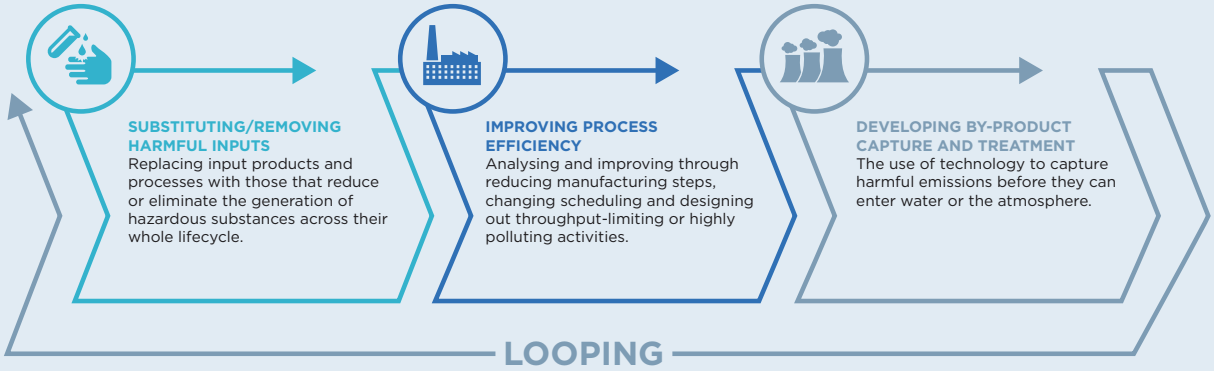
Additionally, moving to compostable, or biodegradable packaging, can mitigate some of the environmental challenges arising from plastic waste today.

## Removing

Removing the need for harmful products altogether – by adopting new or different processes – is another route to eliminating the environmental impacts of production.

Take the example of pigging, a common cleaning process used in manufacturing where a substance is piped. This involves pushing an object through the pipe to squeeze out residual material between changeovers (when equipment is cleaned at the end of a production run and before a new run starts). Traditionally, the process uses a solid object like a rubber bung and is then followed by a cleaning process that uses harmful chemicals. An alternative is ice pigging – a process where an ice slurry is pumped through the pipe instead of a solid object. The abrasive effect of the ice slurry means that no cleaning chemicals are required afterwards, and the material being cleaned out of the pipe can usually be recovered from the slurry.

Figure 2 – AREAS WITH MOST DIRECT IMPACT ON REDUCING HARMFUL ENVIRONMENTAL EMISSIONS IN MANUFACTURING




Looping to develop the business models and technical processes.

# Improving process efficiency

Manufacturing processes tend to grow organically over time, which can lead to processes and equipment becoming outdated. This can be common even in the most advanced manufacturing environments. The scale of the potential opportunity is huge, even in developed economies like the UK. For example, the Institute of Manufacturing estimates that improving resource efficiency could result in an approximate 12 per cent increase in profits and reduce $CO^2$ emissions by 4.5 per cent nationally.[15] Two ways to improve process efficiency are manufacturing reinvention and operational improvement.

## Manufacturing reinvention

Manufacturing reinvention involves designing out aspects of manufacturing processes that slow throughput or use large amounts of raw materials. Below, we look at the common areas of waste in manufacturing processes.



**1. Moving away from a wasteful changeover process**
Factories tend to make multiple different products and variations of products. For example, a textile mill will print many different fabric designs. Every time the design is changed, the rotary screen print rollers need to be removed, have all their ink washed off, and then primed with new ink. This changeover process is very wasteful. Now consider the efficiency that could be gained from moving to a digital inkjet printer. By just changing the software file, a new design could be made. This would also use less water and reduce ink waste and waste from the production of the rotary screen print rollers themselves. Another alternative is to embrace continuous processing techniques in which you no longer have batches of materials and therefore less need to clean machines.



**2. Identifying manufacturing pinch points**
The manufacturing process depends on a few key stages. If the throughput of these is not comparable to that of the wider system, then the whole system slows down. Identifying these and designing them out can change the capacity of whole manufacturing lines for modest investments.



**3. Reducing waste in the process of fabricating products**
The fabrication of products creates waste. In the context of food, this could be lost batches or spill-off from moulds. In textiles this could be fabric off-cuts. There are high-tech solutions available but often simple measures can be taken to achieve big benefits. A focus on training, educating and incentivising staff is of equal importance to improving technology.



**4. Upgrading legacy technology**
New technologies can have a game-changing impact on emissions. However, the high costs associated with implementing them require innovative business models for them to deliver impact. It's important to find a technology solution that works with business ambitions. For example, Dyecoo - the world's first 100 per cent water-free and process chemical-free dyeing solution - has low operating costs that let manufacturers elevate short-term results and long-term goals. The $CO_2$ used is reclaimed from existing industrial processes, with 95 per cent of it recycled in a closed loop system.[16] The company provides textile manufacturers with geographical freedom from water sources and offers a head start on legislation that restricts the use of process chemicals.

Dyecoo – the world's first 100 per cent water-free and process chemical-free dyeing solution – provides textile manufacturers with a way to lower costs. The CO2 used is reclaimed from existing industrial processes, with 95 per cent of it recycled in a closed loop system.

## Operational improvement

Optimising production systems isn't a new concept. Organisations in high-income countries have been doing it for decades to improve performance and reduce waste and negative environmental effects.

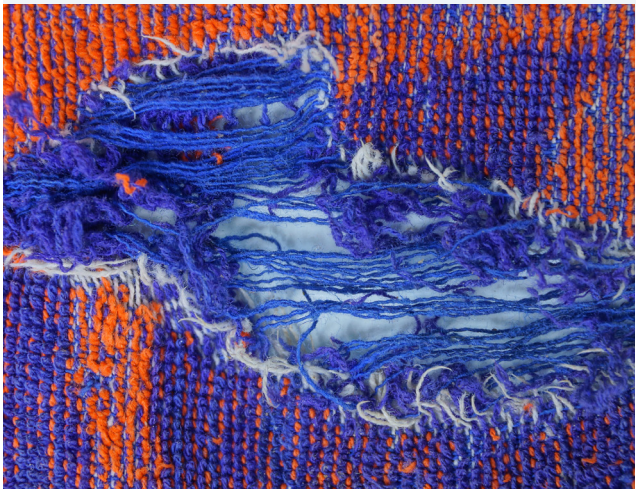
When considering the entire production system, it'simportant to think of waste not just as defective parts or excess material, but as potentially valuable for other uses. Waste is any factor in the production process that doesn't add value. It's helpful for organisations to look at six categories to identify sources of waste:

**1** **MODES OF TRANSPORT USED**

Transport is an essential part of any operation. However, if materials, parts, or finished goods are transported for more than the minimum requirement, the operation is inefficient. Network analysis is most commonly used to evaluate process flows and plant layouts, and to reduce transport waste at the production level.

**4** **REDUCING PRODUCTION DEFECTS**

Defects should be considered waste, as should the cost of inspecting for defects, responding to customer complaints and making repairs. Analysis that targets the root cause of defects generally identifies issues of poor process control, deficient planned maintenance, inadequate training or work instruction, poor product design and poor supplier quality. Understanding these causes helps create methods to reduce them and lessen their impact.



> Ensure employees adopt efficient working practices for waste management and are incentivised to do so.

**2** **SIZE OR NATURE OF INVENTORY**

Traditionally, holding large inventories of stock was a way to compensate for poor production performance and ensure customer supply. It is worthwhile to re-examine inventories to identify potential areas of waste or unnecessary cost.

**3** **AREAS OF OVER-PROCESSING**

Take, for instance, the cleaning of lines between product changeovers. If the products are sequenced correctly, sometimes cleaning is not required. A simple example would be making white paints or dyes first, followed by darker colours.

**5** **LACK OF WORKING PRACTICES FOR STAFF**

Ensure employees adopt efficient working practices for waste management and are incentivised to do so. This can be more of a challenge in environments with high staff turnover or unskilled labour, as found in some low-income countries. On-going training and clear communication are key, as is ensuring your development approach is right for the local environment.

**6** **APPROACH TO DATA COLLECTION**

Finding low-cost ways to automate data collection can help organisations find savings. This can be done through Industry 4.0 thinking, which takes advantage of the Internet of Things to connect manufacturing equipment to networks. This enables real-time monitoring and preventative maintenance.

# Developing by-product capture and treatment

Capturing and, where possible, treating by-products reduces harmful emissions and often create value by making the waste useful. Treatment of the by-product includes everything necessary to get it ready for resale into the market, from processing to proving its provenance. Physical by-products are either gaseous, liquid or solid, and each requires a unique approach to extract value.

## Gases

The energy for manufacturing in low-income countries currently produces a lot of harmful emissions. For example, due to poor electrical grids, around 90 per cent of businesses in Nigeria have diesel generators to supplement their electrical needs. The exhaust these generators emit contain more than 40 toxic air contaminants, including many known or suspected cancer-causing substances, such as benzene, arsenic, and formaldehyde.[17]

Yet the technology to capture harmful substances has been advancing rapidly in recent years. By utilising new technology such as selective catalytic reduction, toxic air emissions can be reduced. It's possible to develop a system that takes this technology and applies it to local energy production in highly populated areas of low-income countries.

## Liquids

It's common in high-income countries to use mobile effluent-treatment plants during maintenance periods or if their main systems go down. These fit into a shipping container. They could provide treatment facilities to factories in areas where no regular and effective effluent treatment is currently carried out. The building blocks for these systems are available off the shelf. However, the exact architecture and chemistry would have to be designed.

## Solids

With by-products, often sorting and identifying the waste is enough to command much great resale values. ReverseResource, for example recently launched a new platform for tracking and tracing production waste from Bangladesh garment factories to recycling. They managed to prove that factories get significantly better price for their waste once they start segregating their waste by market demand. They are in the process of scaling this to cover three other suppliers.

## Looping

In a manufacturing environment, this is often referred to as industrial symbiosis. The term is defined by Waste and Resources Action Programme (WRAP), a charity that works with organisations to achieve a circular economy, as "an association between two or more industrial facilities or companies in which the wastes or by-products of one become the raw materials for another."

For this to happen, business models that enable value to be captured and where the technology is in place to accept and use the by-product.

CASE STUDY

**Using CE principles to capture innovation opportunities for Sri Lanka's textile waste**

Garment manufacturing is Sri Lanka's biggest manufacturing sector, contributing to 61 per cent of exports and 44 per cent of GDP in 2015. However, it has no recycling facilities in the country to deal with the waste it generates.

TransTextile, a project funded by EPSRC Global Challenge Research Fund in 2017, was an eight-month feasibility study to understand the benefits an 'innovation sandpit' – a discussion forum designed to encourage innovative thinking – could bring to the garment manufacturing industry in Sri Lanka. The project combined insight from a range of organisations, including the country's top garment manufacturers, engineering schools, local upcycle designers and an environmental research NGO.

The group identified innovative ideas to help reduce textile waste in the country. Each of the ideas covered a spectrum of technology readiness levels and a range of potential sustainability impacts. Examples included the development of:

**SAMOSA Beanbags**
Using unrecyclable polyurethane (PU) foam offcuts, the group created beanbag chairs called SAMOSA beanbags. These beanbags could divert 300-600 tonnes of PU foam offcuts from landfill each year. They also contribute to a CE by providing opportunity to repurpose the materials in a leasing scheme.

**High-press fibre panels**
A sustainable replacement for construction panel materials, the high-press fibre panel transforms polyester offcuts into panels. Because the creation of these panels requires no bonding material to be used, it ensures materials can be looped at the end of their lifecycle.

**DenimTile**
Sri Lanka has a growing high-end interior design market and DenimTile was developed to maximise denim offcut consumption by using it for various decorative applications. It's anticipated that the solution will divert 600 tonnes of fabric offcuts from landfill per year.

This project demonstrated the importance of driving collaboration through a local network hub to pave the way for a more sustainable future for Sri Lanka's garment manufacturing industry.[18]

# 4 HOW TO SUPPORT THE TRANSITION TO A CIRCULAR MANUFACTURING PROCESSES

The CE is redesigning how resources and materials flow across organisations, unlocking opportunities to drive value.

The opportunities are ripe for low-income economies to transform their approach to manufacturing. As these economies explore CE principles, they will find obstacles to progress. In this chapter, we examine the challenges and assistance needed, and the commercial opportunities that circular approaches represent for low-income countries. The four key areas we explore are:

- overcoming the barriers of the circular economy
- defining new roles for government, donors and the private sector
- adopting innovative business models
- encouraging emergent circularity.

# Overcoming the barriers of the circular economy

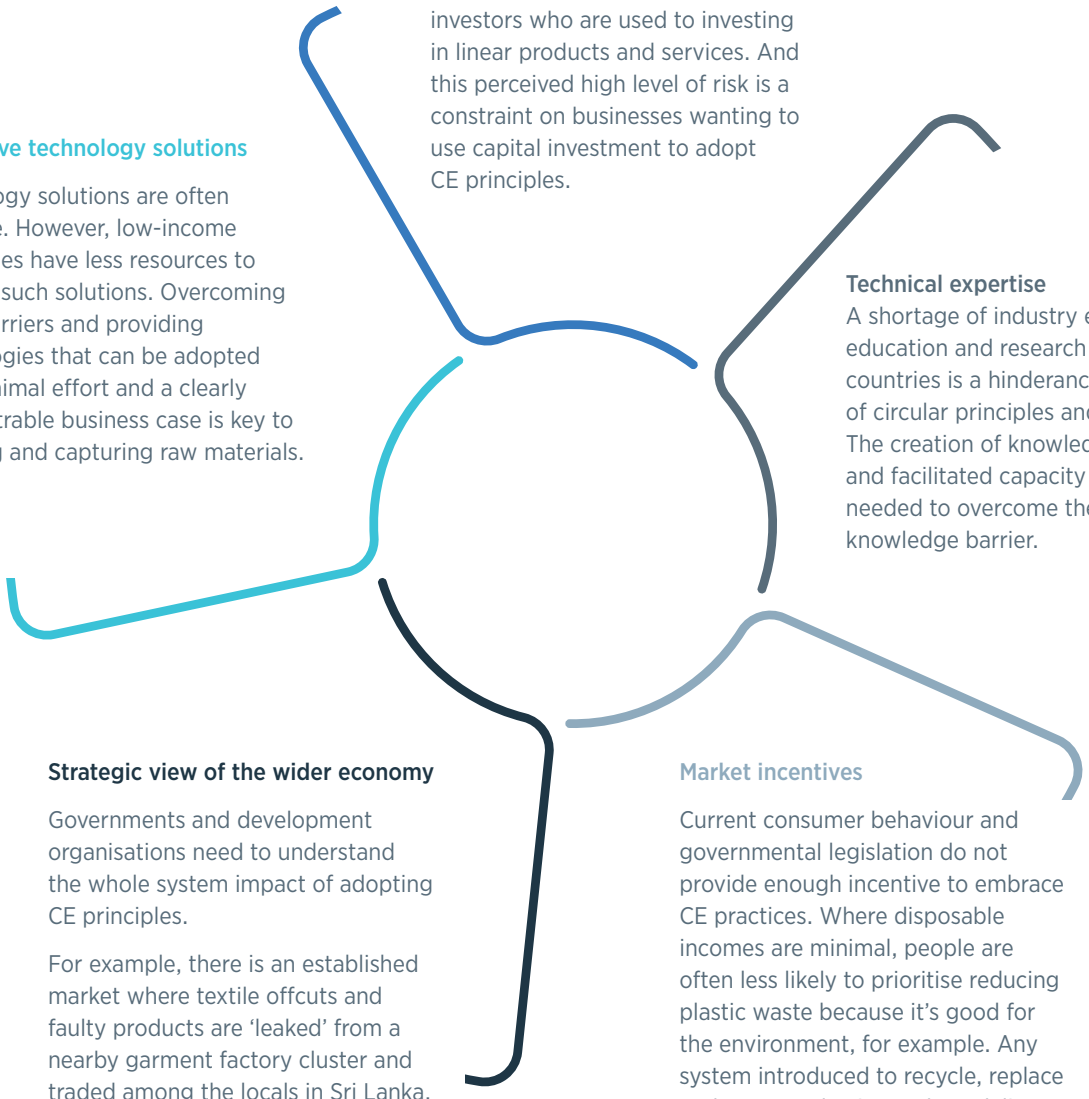
The CE has the potential to unlock untapped value in manufacturing in low-income countries. To seize this opportunity, five barriers must be overcome:

### Capital investment

There is uncertainty about the transition costs for companies adopting CE methods, and about its impact on business models and revenues. This creates new risks for investors who are used to investing in linear products and services. And this perceived high level of risk is a constraint on businesses wanting to use capital investment to adopt CE principles.

### Innovative technology solutions

Technology solutions are often available. However, low-income economies have less resources to develop such solutions. Overcoming these barriers and providing technologies that can be adopted with minimal effort and a clearly demonstrable business case is key to reducing and capturing raw materials.



### Technical expertise

A shortage of industry expertise, education and research in developing countries is a hinderance to the rollout of circular principles and incentives. The creation of knowledge networks and facilitated capacity building are needed to overcome the significant knowledge barrier.

### Strategic view of the wider economy

Governments and development organisations need to understand the whole system impact of adopting CE principles.

For example, there is an established market where textile offcuts and faulty products are ‘leaked’ from a nearby garment factory cluster and traded among the locals in Sri Lanka. Textile optimisation would reduce the source of income for those who make their livelihood using these materials. Understanding this whole system impact and potentially creating alternative job opportunities for those affected would be an important factor in mitigating the consequences of such action.

### Market incentives

Current consumer behaviour and governmental legislation do not provide enough incentive to embrace CE practices. Where disposable incomes are minimal, people are often less likely to prioritise reducing plastic waste because it’s good for the environment, for example. Any system introduced to recycle, replace and remove plastic needs to deliver a financial reward to those participating to be adopted and sustained.

Encouraging local consumption to drive circularity, with micro economies around specific industries and by-productss, will prove cost benefits at global scales.

# Defining new roles for government, donors and the private sector

National governments, international donors and the private sector play a pivotal role in low-income countries, helping them to adopt CE principles. Progress is likely to depend partly on the maturity of the business system. But there are areas where actors can promote the adoption of CE principles in manufacturing.

## ADOPT CE PRINCIPLES ACROSS THE GOVERNMENT

Governments will need to lead the change and provide opportunities through their own initiatives. This will help to engage new actors and incentivise them to adopt circular principles.

## CAPACITY BUILDING

The CE is still a young concept, and knowledge and understanding can be even more limited in low-income countries. This can be addressed through collaborative initiatives such as sharing industry best practice, training stakeholders and articulating niche insight, as well as providing access to new learning resources and research opportunities.

## ENACT ENVIRONMENTALLY FRIENDLY MANUFACTURING LEGISLATION

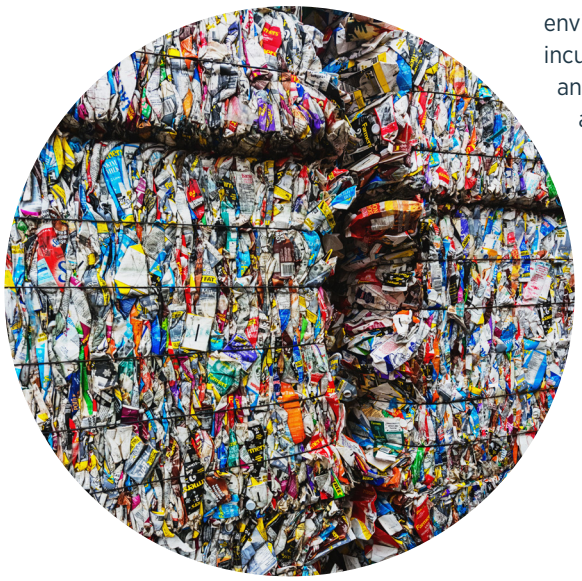
National governments can reform tax systems and legislation to encourage circular business models and discourage pollution and waste. One way of doing this is through environmental taxation, which provides incentives for organisations to focus on efficiency gains, green investment, innovation and shifts in consumption patterns.

## DRIVE AND SUPPORT CHANGE THROUGH THE WHOLE VALUE CHAIN

Private sector companies are increasingly aligning their operations with sustainable development, and driving change through the whole of their value chain. It's important that a high level of ambition is set, predicated on disruptive technology and business models, and that meaningful support is provided at the local level to ensure the solution can achieve its maximum impact, whilst minimising negative social and economic impact.

## PROACTIVELY ADDRESS THE TRANSITION COSTS

Transforming from a linear economy into a circular one requires a major transformation of production and consumption patterns. This would affect the economy, the environment and society. And it would incur costs in areas such as R&D, subsidies and infrastructure spending. A proactive and coordinated response by donors and national governments will create a strong foundation for circular activities.



> Governments will need to lead the change and provide opportunities through their own initiatives.

# Adopting innovative business models

By adopting CE principles in their industrial strategies, low-income countries are likely to create new business opportunities for manufacturers. Changes in technology will see new approaches to how both large and small organisations valorise and recover waste.

> **New cost-effective technologies and approaches could be created that can process waste into valuable manufacturing feedstock.**

For existing manufacturers, the opportunities are improved productivity, a healthier workforce and reduced operational costs. Below are a few examples of where innovations could prosper:

### Resource recovery models

It's possible to create cost-effective technologies and approaches that can process waste into valuable manufacturing feedstock. For example, a brass recycler in Thailand turns scraps from machining into purer brass. In addition, it harvests zinc oxide from the recycling process and sells it to a cosmetic manufacturer as a key ingredient in sunblock.

### Skilled service providers

New technological equipment and resource material creates demand for skilled employment, such as service operators, training experts and maintenance engineers. These innovative business models could also develop new industries, as demand may increase for new financing agreements or refurbishment treatments.

### Flexible manufacturing

As manufacturing becomes increasingly affordable and responsive, approaches such as additive manufacturing will enable far more efficiency. The benefits range from less waste to personalised, on-the-spot production.

### Circular suppliers

As waste will still be produced, there will be demand for recovering (but not processing) it and moving it to where it's useful.

### Collaborations

New markets will be created to facilitate collaborations and bring products to consumers in an effective, efficient and closed-loop process.

# Encouraging emergent circularity

A faster, wider transition to the CE requires a multi-dimensional grass-roots approach in conjunction with top-down approaches from the government. Implementing a local support system to boost bottom-up circular entrepreneurial activities could accelerate the transition and empower people in low-income countries.

Some models and initiatives that can support this include:

### Creating innovation hubs

Innovation hubs are a great way to bring regional authorities, business, academics and aspiring entrepreneurs together for a common objective in regions where there is a lot of industrial activity, but where limited access to the knowledge and technology impedes emergent circular entrepreneurship.

### Runnings hackathons

Focussed on circular waste, these events could bring together participants to work collaboratively on a given challenge.

### Community and entrepreneur clubs

Bringing together hidden CE champions in the region and local pioneers can empower individuals who have been struggling to address the environmental issues separately.

# ABOUT THE REPORT

This report was informed primarily by desk-based research and conversations with experts in the field. We created this report in 2019 in collaboration with the Department for International Development (DFID). We gathered insight from our experts in the circular economy (CE), and conducted research to identify trends, best practice and examples of how CE principles can transform manufacturing in low-income countries.

## Footnotes

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Mark co-leads PA's work with sustainability and circular economy clients. Mark specialises in organisational design and transformation, helping clients execute strategy effectively. Mark believes the circular economy will increasingly be a disruptive force, and that businesses need to understand the opportunities and challenges it presents.


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David co-leads PA's work with sustainability and circular economy clients. He focuses on delivering complex, multidisciplinary technology projects and brings a pragmatic approach. With over 15 years' experience from across the public and private sector, David enjoys working with creative teams of engineers, designers and scientists in the early stages of development to help clients deliver disruptive products and services.

# GET IN TOUCH

Contact the team to discuss our recommendations and how we can help your organisation embrace the circular economy.

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**About PA.**

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