

**CIRCULAR ECONOMY IN INDIA:
RETHINKING GROWTH FOR
LONG-TERM PROSPERITY**



ELLEN MACARTHUR
FOUNDATION

Executive summary

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In a context characterised by unprecedented economic dynamism and a rapidly growing population, India stands at the threshold of profound choices about the path to future development. If it continues, the country's economic growth trend, which averaged 7.4% a year in the last decade, will lead it to become the fourth largest economy in the world in about two decades.¹ This positive prospect does not, however, come without challenges as the nation still faces significant questions about rapid urbanisation, resource scarcity, and high levels of poverty.

In an interconnected world predicated largely on a linear economic model, the upcoming Indian powerhouse could embark on an industrialisation path comparable – albeit faster – to that of mature markets, with the associated negative externalities it entails. But this scenario is not inevitable. With its young population and emerging manufacturing sector, the country is at a crossroads and can today make systemic choices that would put it on a trajectory towards positive, regenerative, and value-creating development.

Business leaders and governments around the world are increasingly looking beyond the linear 'take, make, dispose' model of growth, with a view to operate a strategic move towards an approach fit for the long term. Past research by the Ellen MacArthur Foundation and others has demonstrated the potential of the circular economy – one that is restorative and regenerative by design and makes effective use of materials and energy in a digitally-enabled model of development.

This report shows that a circular economy path to development could bring India annual benefits of ₹40 lakh crore (US\$ 624 billion) in 2050 compared with the current development path – a benefit equivalent to 30% of India's current GDP. This conclusion rests on high-level economic analysis of three focus areas key to the Indian economy and society: cities and construction, food and agriculture, and mobility and vehicle manufacturing. The research shows that realising these benefits fully would require applying circular economy principles in combination with harnessing the unfolding digital and technological transformation, all tailored to the Indian context.

In addition to creating direct economic benefits for businesses and households, following a circular economy development path would reduce negative externalities. For example, greenhouse gas emissions would be 44% lower in 2050 compared to the current development path, and other externalities like congestion and pollution would fall significantly, providing health and economic benefits to Indian citizens.

Achieving these benefits would require Indian businesses to lead the way in the transition phase, with policymakers simultaneously setting the direction and creating the right enabling conditions. Other organisations, such as universities, non-profits, and international organisations can play important supporting roles, including facilitating and participating in local collaborative initiatives.

By embarking on a circular economy transformation – launching new circular economy initiatives and reinforcing existing efforts – India could leverage its expected high levels of growth and development to build a more resource-effective system, creating value for businesses, the environment, and the Indian population.

In support of the report

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“India has the opportunity to save money, make money and do good by adopting the principles of the circular economy. It has the opportunity to leapfrog other economies and establish a leadership position. This ‘must read’ report provides a framework and practical recommendations for three vital sectors of the economy namely agriculture, construction and transportation.”

MR RANGASWAMI, FOUNDER, CORPORATE ECO FORUM

“Traditionally, the Indian economy has been one where reusing, re-purposing and recycling has been second nature. In a world that is increasingly running out of natural resources, this thinking is an asset that must be leveraged by businesses, policymakers and citizens in an organised manner and expanded to include other elements to make the economy truly circular. Many companies in the Tata group already implement some of the principles of a circular economy and we would continue to explore opportunities to expand this; it makes business sense and furthers our mission of improving the quality of lives of communities we serve globally.”

SHANKAR VENKATESWARAN, CHIEF - TATA SUSTAINABILITY GROUP

“Increasing circularity is paramount to unlock efficiencies in a world which needs urgent investment opportunities in sectors which deliver environmental, economic and social gains. Lessons from this work in India can serve as an important example for other developing countries seeking to implement policies to meet the SDGs and the commitments in the Paris Agreement.”

AMBASSADOR GUILLERMO VALLES, DIRECTOR FOR INTERNATIONAL TRADE IN GOODS, SERVICES AND COMMODITIES, UNCTAD

“This ground-breaking report shows how India can significantly benefit from a circular economy - creating jobs and cutting pollution. Construction, mobility and agriculture in India can be re-purposed to offer more-for-less by designing out waste, digitising production and consumption and optimizing the use of economy wide assets. India can leapfrog the ‘take-make-waste’ traditions of industrialized countries, and offer its consumers a new path to prosperity. This opportunity needs smart policy and business champions. With these ingredients India can rise to new heights.”

DAN HAMZA-GOODACRE, CLIMATEWORKS

“Beyond design practice and economic models, the circular economy will also affect the nature of collaboration - well beyond existing practices. We need new procurement - making commitments between all parties based on mutual gains. This will be a big disruption to existing practices from finance to contractual arrangements. It will upset our own sector, a big challenge but an opportunity to re-shape how we work.”

CAROL LEMMENS, DIRECTOR, GLOBAL MANAGEMENT CONSULTING BUSINESS LEADER, ARUP

“India is committed to the goals set out in the SDGs. It ratified the Paris Agreement on 2 October 2016, coinciding with the birth anniversary of Mahatma Gandhi. India is earnestly working towards finding ways to improve the standard of living of its citizens, compatible with its resources. Increasing circularity in the Indian economy, by better utilisation of materials, energy and innovative ideas ranging from India’s traditional knowledge to latest technologies will be very important to realise India’s sustainability goals over the next decades. Sectors such as mobility, agriculture and construction will play a crucial role in the future growth of India. The suggestions contained in the report are, therefore, noteworthy and timely.”

H.E. MR AJIT KUMAR, AMBASSADOR AND PERMANENT REPRESENTATIVE OF INDIA TO THE UNITED NATIONS OFFICE AND OTHER INTERNATIONAL ORGANIZATIONS IN GENEVA

“The arguments for choosing more sustainable strategies for national development – giving attention not just to their economic but also to their social and environmental outcomes – apply to all countries, advanced or emerging, rich and poor. The ones, such as India, trying to catch up in the race to create better lives for their citizens, however, face resource constraints – natural, physical, financial and human – that make those choices doubly difficult, yet just as imperative. The concept of circular economy, a metaphor that neatly resonates with Mahatma Gandhi’s ardent lifelong quest for efficiency in production, sufficiency in consumption and what he could well have called “conservancy” of resources and ‘deficiency’ in wastes, captures well the desirable characteristics of the future we will all have to live in – and how to get there. It is only to be hoped that governments, businesses and civil society in India will come together and draw upon these traditional and yet highly modern values in creating a vibrant, prosperous and fulfilling future for the nation. The insights of this Report will probably be of considerable value to other economies as well.”

ASHOK KHOSLA, CHAIRMAN, DEVELOPMENT ALTERNATIVES, CO-CHAIR, INTERNATIONAL RESOURCE PANEL (2007-2016)

“In the 70s, when I grew up in India, we practiced circular economy principles without even knowing it: we wasted no resources and reused everything. With rapid modernisation of its economy, however, India is losing touch with its frugal roots. This report convincingly shows how India can rekindle its frugal consciousness and implement circular value networks that would set new global benchmarks for efficiency and sustainability.”

NAVI RADJOU, COAUTHOR OF FRUGAL INNOVATION: HOW TO DO BETTER WITH LESS AND FELLOW, JUDGE BUSINESS SCHOOL, UNIVERSITY OF CAMBRIDGE

“The world’s growing and the increasingly affluent population has caused an overuse of resources, higher price levels and increasing market volatility. In this scenario I believe that the circular economy model could be a game changer. We at Mahindra group are conscious of this and are innovating to create production models that reduce our reliance on virgin raw materials through reduce, reuse, recycle and upcycle. We recognise that the future of a circular economy for a transitioning economy like India involves incorporating the informal sector in discussions and assigning them a recognisable place in the value chain. I am happy to see that circularity has already started to make inroads into our linear economy, with innovative products from waste being introduced in the markets. At Mahindra we also work closely with our supply chain as positive influencers and are happy to be part of this story. ‘Circular economy in India’ by the Ellen MacArthur Foundation is an attempt to understand the needs of these very markets and could serve as an eye opener to the possibilities for circular economy in our country.”

ANIRBAN GHOSH, CHIEF SUSTAINABILITY OFFICER, MAHINDRA GROUP

“India’s growing manufacturing ambition is going to bring global issues of excessive waste with it. Hence considering discarded materials/products as legitimate raw materials with circular economy approach is the only way forward.”

SHUBHI SACHAN, PUNĀH PROJECT INITIATOR AND LEAD, GODREJ & BOYCE

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Disclaimer

This report has been produced by a team from the Ellen MacArthur Foundation, which takes full responsibility for the report's content and conclusions. UNCTAD served as a knowledge partner for the project. While the members of the steering committee and advisory panel, and the experts consulted acknowledged on the following pages have provided significant input to the development of the report, their participation does not necessarily imply endorsement of the report's contents or conclusions.

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Table of contents



Executive summary	3
In support of the report	4
Acknowledgements	6
SUMMARY OF FINDINGS	10
CHAPTER 1 – RETHINKING VALUE CREATION: THE CIRCULAR PERSPECTIVE	18
CHAPTER 2 – WHAT A CIRCULAR ECONOMY COULD LOOK LIKE IN INDIA	26
Cities and construction	30
Food and agriculture	40
Mobility and vehicle manufacturing	48
Benefits of a circular economy for India	55
CHAPTER 3 – CAPTURING THE BENEFITS	58
APPENDICES	66
Appendix A: Comparison of development paths to 2050	68
Appendix B: Applying circular economy principles in other emerging economies	72
Endnotes	73

Summary of findings

While the business benefits of a circular economy globally are well understood² and the opportunities for high-income countries (especially in Europe) have been studied,³ limited proof points are available for countries with high economic growth and rapid societal changes (e.g. expanding population, urbanisation, and growing middle class).⁴ Taking these factors into account, this report looks specifically at circular economy opportunities in India, providing a starting point for exploring the benefits of a circular economy for emerging economies.*

Recent initiatives by businesses, government bodies, and non-profits in India are aligned with the principles of a circular economy. Several aspects of circularity are deeply ingrained in habits, as exemplified by high rates of utilisation and repair of vehicles and the distributed recovery and recycling of materials post-use. Often handled informally, these activities provide the only source of livelihood for some of the poorest sections of the Indian population.

However, because these activities tend to happen at the end of the value chains, with little upstream effort to enable effective recovery, they have sub-optimal economic and environmental impact and present health risks for the people involved. As the Indian economy and middle class continue to grow, these practices will become less attractive, unless a more systematic approach is taken to modernise them and move them up the value ladder. Moreover, as India becomes increasingly connected to the global market and its predominantly linear supply chains, economies of scale may pull the country towards the same one-way model of growth that mature markets embraced, further reducing the impact of current circular practices and potentially creating a linear lock-in.

An ambitious long-term vision of a circular economy, built on the current strengths of the Indian market and engaging business, policy, and education in its realisation, could, on the contrary, provide the basis for a regenerative development path towards long-term prosperity.

This report identified circular economy opportunities in three focus areas: cities and construction, food and agriculture, and mobility and vehicle manufacturing. Household expenditure in these three areas taken together (housing, food, and mobility) accounts for more than two-thirds of average household spend in India, both in urban and rural areas.⁵ They cover the two largest industrial sectors in terms of employment (agriculture and construction) and growth expectations (construction and vehicle manufacturing).

The insights of the report rest on both research and analytical modelling. In addition to extensive desk research, the research included interviews with some 40 local and international experts and several workshops and meetings in India, bringing together more than 80 expert participants from business, government, universities, non-profits, and other organisations. Detailed analysis was carried out comparing costs and externalities between the current scenario and a circular economy scenario in the three focus areas in 2030 and 2050 (see *About the analysis*). The work resulted in insights on the benefits a circular economy could have for India and recommendations on how to capture these benefits.

ABOUT THE ANALYSIS

The analysis takes into account expected population growth, urbanisation trends, and demand for increased quantity and quality of housing, food, and mobility. The current development path takes into account expected technological development and optimisation trends, while the circular development path uses a system-based approach leveraging circular economy opportunities.

For India as a country with a growing economy and population, the analysis compared costs and externalities in the two development scenarios, rather than comparing future values with today. Costs compared are cash-out costs and do not include opportunity costs or monetisation of externalities. All costs are in 2015 Indian rupees.

* Some information on insights from this report that could inform investigation of circular economy opportunities in other emerging economies can be found in Appendix B.

The case for a circular economy in India

The research and analysis established seven key insights that make the case for the application of circular economy principles in India.



A circular economy development path in India could create annual value of ₹14 lakh crore (US\$ 218 billion) in 2030 and ₹40 lakh crore (US\$ 624 billion) in 2050 compared with the current development scenario. This conclusion emerges from comparison of costs in the three focus areas. The analysis indicates that costs to provide the same level of utility would be significantly lower in the circular development scenario. Cost savings amount to 11% of current Indian GDP in 2030 and 30% in 2050.

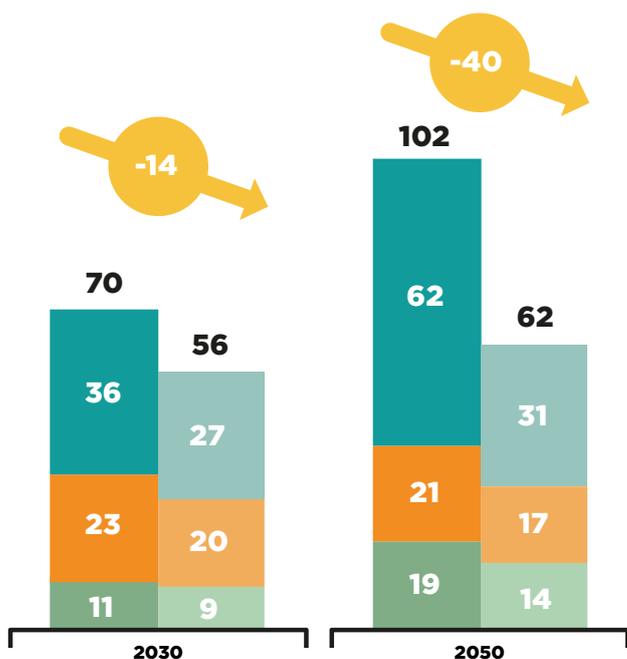


By adopting circular economy approaches, businesses could achieve material cost savings and increase their profits. The key drivers of value creation include better product design, innovative business models, and reverse logistics.

For example, shifting from selling cars to providing vehicles as a service can create new revenue streams for the automotive industry and capture the value of more intensive use of each car. Innovative vehicle design to make maintenance easier and boost fuel efficiency

FIGURE 1: COMPARISON OF CASH-OUT COSTS IN POTENTIAL DEVELOPMENT PATHS

TOTAL CASH-OUT COSTS IN THREE FOCUS AREAS (₹ LAKH CRORE)



	CURRENT SCENARIO	CIRCULAR SCENARIO
MOBILITY AND VEHICLE MANUFACTURING		
FOOD AND AGRICULTURE		
CITIES AND CONSTRUCTION		



can create value by increasing utility (in terms of total kilometres driven) and decreasing running costs. In the built environment, construction companies can innovate by applying design methods for modular buildings. Retrieving materials left over after construction and demolition work and keeping them in cycles could capture their value and ultimately reduce overall construction costs.

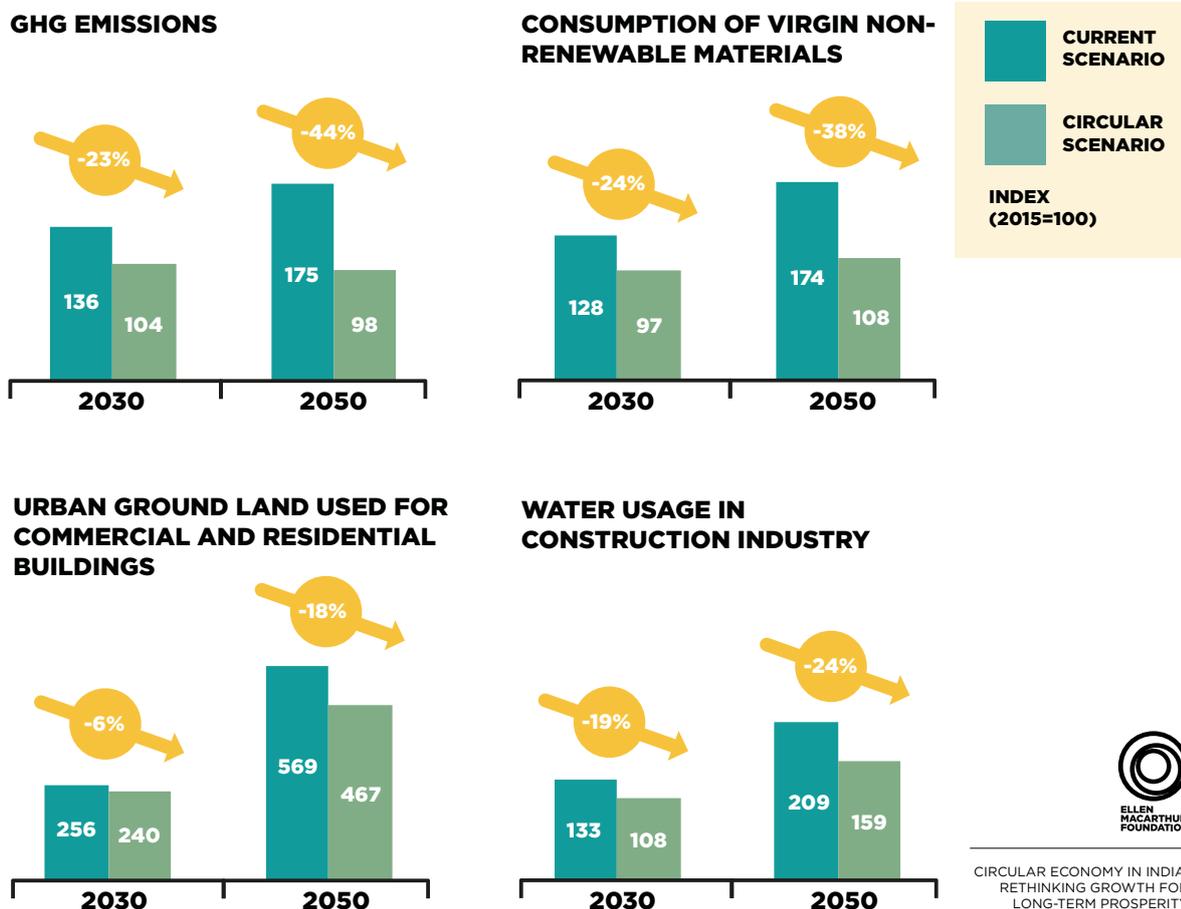
Indian businesses in industries beyond those analysed for this report could also realise profit opportunities. For example, an earlier analysis by the Ellen MacArthur Foundation, based on detailed product-level modelling, found a global value creation potential of up to US\$ 700 billion a year for fast-moving consumer good companies at today's consumption levels.⁶ The expected growth of the Indian middle class suggests that this implies significant opportunity for Indian businesses in industries with rising local consumption, such as textiles and electronic equipment. Both established businesses and new entrepreneurial initiatives could capture these profit opportunities.

3

A circular economy development path could significantly mitigate negative environmental externalities. For example, greenhouse gas (GHG) emissions could be 23% lower in 2030 and 44% lower in 2050 compared with the current development scenario, helping India deliver on its targets promised in the recently ratified Paris agreement. This comparison is derived from the accumulated emissions in the three focus areas (see p. 57 for details). Other negative externalities, such as those resulting from the linear use of virgin materials and water, and the consumption of synthetic fertilisers, would also decrease.

In the three focus areas analysed, virgin material consumption would be 24% lower in 2030 and 38% lower in 2050 compared with the current development path. Water usage in the construction industry would be 19% lower in 2030 and 24% lower in 2050, while synthetic fertiliser and pesticide use would be 45% lower in 2030 and 71% lower in 2050 compared to the current development path (see Figure 2).

FIGURE 2: COMPARISON OF POTENTIAL DEVELOPMENT PATHS



4

A circular economy could deliver benefits for the Indian population, such as cheaper products and services and reduced congestion and pollution.

In all three focus areas studied, the analysis showed that the cost of providing the expected services for each citizen would be considerably lower on the circular development path than on the current path. While businesses will capture part of this value, most of it would boost disposable income. The lower costs could also help India implement such initiatives as Pradhan Mantri Awas Yojana (Housing for All) and the National Food Security Mission.

The analysis also suggested beneficial impact on congestion, pollution, and health. For example, following the circular development path would reduce vehicle kilometres travelled on roads by 38% in 2050, compared with the current path, and reduce congestion and time spent in traffic. The circular scenario would also include more zero-emission vehicles reducing pollution and their associated negative effects on health and costs. Reduced use of pesticides (76% lower in 2050 compared with the current path) is likely to improve the health of farmers.

Detailed modelling of systemic externalities, which exceeds the scope of this analysis, would be necessary to estimate more precisely the broader systemic impact of applying circular economy principles in India.

5

Leveraging digital technology to enable the circular economy could reinforce India's position as a hub for technology and innovation.

The interplay between circular economy and digital technology creates fertile ground for value creation and given its renowned IT sector, India is particularly well positioned to leverage these opportunities. All three focus areas studied could leverage digital technology and the increasing ease of connectivity.

For example, in the food system, digitised supply chains and platforms for sharing assets (thus maximising their utilisation rate) and knowledge (best practices) among small farmers can create significant benefits. In the mobility sector, digital devices can provide seamless door-to-door transport planning, combining diverse modes of transport, and providing direct access to mobility when it is needed. In cities, digitally enabled sharing solutions are already being deployed to increase the utilisation of floor space in buildings.

Pairing circular economy principles with digital intelligent assets (internet of things) generates many additional value creation opportunities,⁷ which both established businesses and emerging entrepreneurs could capture. Current government initiatives, like Digital India, could support these opportunities by embracing circular economy principles.

6

By actively leveraging and reinforcing circular economy opportunities now, India could move directly to a more effective system and avoid getting locked into linear models and infrastructure.

As the systems that provide housing, food, and mobility require development in a growing economy like India's, the country could realise significant value by developing them in a circular, rather than a linear, way.

For example, only about 2% of the Indian population currently owns a car, but the demand for mobility is increasing. Designing and building a mobility system that enables safe, convenient, and comfortable travel without car ownership could meet people's mobility needs with lower cost and fewer negative externalities than in the current development scenario. In other areas, such as cities and the construction industry, satisfying the demand for development with highly efficient infrastructure and buildings – or virtualising the needs altogether, which in turn has a beneficial impact of the mobility system – could reduce consumption of resources and energy for many years.



High-growth markets like India can achieve competitive advantage over mature economies by moving to a circular economy.

As explained above, applying circular economy principles to new activities from the start would firmly set the direction of travel and favour early success. In contrast, because of existing linear lock-in, mature economies would need to transform large parts of their systems to reach the same level of circularity. This advantageous starting

point could provide India and other high-growth markets with a competitive advantage over those economies.

For example, 70% of the buildings expected to stand in India by 2030 are not yet built,⁸ compared with 25% in the UK.⁹ If both economies applied circular economy principles to all new construction until that year, India's buildings would have higher embedded circularity. India could leverage this competitive advantage by developing circular construction skills and innovation to export to other countries. Similarly, the total costs (relative to the size of the economy) of shifting to a highly circular system would be much lower for India.

Circular economy opportunities for India

Cities and construction: liveable cities with buildings and infrastructure that meet the future needs of India's expanding population

India is urbanising at an unprecedented rate, against a backdrop of resource constraints. An estimated 700-900 million square metres of new commercial and residential space a year – the equivalent of what exists in Chicago today – needs to be built to cope with the increasing demand.¹⁰

Circular economy principles can contribute to this construction activity in ways that create economic value and decouple development from the use of virgin, non-renewable resources. Renewable and recycled materials and modular construction methods can minimise waste and reduce construction costs. Buildings can be designed to be adaptable to changing needs and contribute to the regenerative urban ecosystem during their use phase (energy generation, connection to nutrient cycling systems, etc.).

As India invests in long-term infrastructure to improve citizens' quality of life, for example through the Smart Cities Mission, it could incorporate circular economy principles into the design of the infrastructure needed to provide water, sanitation, and waste services at scale, creating effective urban nutrient and material cycles. More systemic planning of city spaces, integrated with circular mobility solutions, can contribute to higher air quality, lower congestion, and reduced urban sprawl. Flexible use of buildings and urban spaces, enabled by digital applications, can increase utilisations

rates, getting more value out of the same assets. Higher efficiency and lower overall building and infrastructure costs could also help meet the housing needs of the urban poor without compromising safety and quality.

Food and agriculture: a regenerative, restorative agricultural system that combines modern technology with traditional practices to meet India's growing food demand

Employing half of the country's working population,¹¹ the agricultural sector remains essential to the Indian economy and vital to the nation's food security. An agricultural system geared towards closing nutrient loops could give the sector a framework for retaining natural capital, boosting economic and ecological resilience, and delivering a stable supply of fresh, healthy, and diverse food to India's growing population.

Leveraging the current small-farm structure, India could create large-scale networks of farmers, interconnected and symbiotic in their practices and committed to regenerative approaches. Combining local knowledge and traditional methods (like working with a large variety of species) with modern technology (like precision farming, and digitally enabled asset- and knowledge-sharing systems) could increase yield while significantly decreasing requirements for resources such as water, synthetic fertilisers, and pesticides.

Reducing food waste across the supply chain could make the Indian food system even more effective. This would require optimising production and digitising food supply chains to match supply and demand more easily. Urban and peri-urban farming can bring food production closer to consumption, reducing food waste and transportation requirements. Composting and anaerobically digesting food waste with no other valuable use and post-consumption nutrients (those contained in human excreta) allows restoration of nutrients to the soil and production of energy.

Mobility and vehicle manufacturing: a convenient, multimodal transport system enabled by digital technology, for resource-optimised and efficient mobility

Demand for personal mobility in India is expected to double or even triple by 2030.^{12,13} Car sales are booming, and the country is expected to become the third largest market in the world by 2030, after China and the U.S.¹⁴

Circular economy principles can contribute to a mobility system that would meet the growing needs of the Indian population, especially in cities, while limiting negative externalities, such as GHG emissions, congestion, and pollution.

A multimodal, door-to-door, on-demand mobility system, embracing vehicle-sharing trends and leveraging digital innovation, could provide efficient and effective transportation with high vehicle usage and occupancy rates. Mass transit as the backbone combined with other forms of transport – including vehicle as a service – for convenient last-mile connectivity can create convenient door-to-door journeys. Technological innovation can help plan these journeys and make travelling safer and faster.

Taking reparability, remanufacturing, and recycling into account in vehicle design and creating the appropriate reverse cycle infrastructure can reduce the need for virgin, non-renewable resources and energy. Building vehicles that rely on zero-emission propulsion technology could reduce negative externalities like GHG emissions, pollution, and dependence on imported fossil fuels. As car ownership is currently low, adoption could be rapid as ownership expands.

Capturing the benefits

Capturing the circular economy benefits identified in this report would require action by various stakeholders. Analysis of the opportunities and associated challenges in the three focus areas led to the formulation of recommendations for businesses, policymakers, and other organisations. More details and examples on the recommendations can be found in Chapter 3 – Capturing the benefits.

Indian businesses are well placed to lead the way in the transition. Businesses stand to realise substantial profit from the circular economy opportunities outlined in this report. Five recommendations could guide companies seeking to capture this value.

- **Build circular economy knowledge and capacity.** Taking maximum advantage of circular models requires decision-makers throughout the organisation to understand the benefits and take them into account in business decisions. To put circular economy principles into practice, current and prospective employees need training on circular product design, new business models, and reverse logistics.
- **Innovate to create new products and business models and demonstrate their success.** Being at the forefront of implementing circular economy principles and digital technology can create competitive advantage and critical industry momentum. Businesses can foster innovation to address challenges, such as transition costs, more rapidly by collaborating with research institutions and by making information open source. Both established businesses and start-ups can profit from the innovation opportunities, providing an attractive outlet for entrepreneurship in India. Successful pilot projects can demonstrate the value of circular economy models internally and externally.

- **Integrate circular economy principles into strategy and processes.** To have the right incentives for value creation in place, circular economy aspects should be taken into account when designing an organisation's governance structure and decision-making processes. In particular, this would mean including incentives for medium- and long-term value creation opportunities – as well as for cross-functional collaboration – in company strategy.
- **Collaborate with other businesses, policymakers, and the informal economy.** Participation in pre-competitive collaboration in cross-industry and cross-value-chain networks can enable businesses to drive change that they cannot create on their own. Opportunities include leveraging industry cooperative networks and collaborating on specific issues that require systemic problem-solving, such as complex reverse logistics. Tapping activities of the informal economy (e.g. existing repair and recycling activities for vehicles), in cooperation with the public sector or other organisations, allows for additional value creation.
- **Invest in circular economy opportunities.** While sizing and prioritising the value of investment related to the circular economy opportunities outlined in this report requires detailed analysis, the circular economy offers attractive opportunities for both businesses and financial institutions. Companies could moreover scale back investments in linear business models to avoid risks of exposure to greater market volatility and stranded assets.

Governments can set direction for the transition and create the right enabling conditions. Five recommendations could guide policymakers at national, state, and local/city levels in supporting the transition in the medium- and long-term.

- **Set direction and show commitment.** Clear policies and communication can encourage private and public investment in relevant research and business development. While scattered existing provisions and regulations include some circular economy principles, advancing the transition requires a coherent focus and systematic approach, including integration of circular economy ideas into existing government initiatives. Policies could, for example, provide targets and strategies. Clear and binding policies, laid out in a roadmap, would provide the visibility needed to coordinate infrastructure development and investment planning.
- **Create enabling regulatory frameworks and remove policy barriers.** Some current policies, typically focused on individual areas rather than taking a systemic view, cause unintended barriers to adopting circular business models. Detailed analysis of regulations in each sector – conducted with businesses and other relevant stakeholders – could identify these barriers and provide a basis for recommending policy changes that support circular economy opportunities.
- **Create platforms for multi-stakeholder collaboration.** Collaboration among stakeholders to address key issues is critical to achieve systemic change. For example, inroads to addressing India's solid waste management challenge could be made by connecting all kinds of actors along the value chain, including producers, municipalities, the informal sector, waste management companies, and research institutions.
- **Support circular models through public procurement and infrastructure.** Using a circular procurement approach, public organisations could acquire goods and services in a way that achieves value for money throughout a product's use, while minimising material losses and adverse environmental impacts. Public procurement recommendations that support promising, scalable circular business models, from both emerging and established innovators, could help kick-start those models to stimulate their wider adoption in the market. Focusing infrastructure investments on infrastructure such as integrated post-use collection systems and sorting and reprocessing facilities could support circular economy activity and investment by the private sector.
- **Embed circular economy principles into education.** Bringing circular economy principles into education, from school through to professional development, can equip learners with the right systems thinking skills and mindsets to become active shapers of a circular economy. Increased access to information, for example through open-access courses, helps bridge knowledge gaps, reduce scepticism, and increase awareness of the value of circular models.

Various organisations, including universities, non-profits, and international bodies, can play important supporting roles in the transition to a circular economy. They might, for example, conduct research and pilot projects to create a knowledge base and establish proof points, represent the interests of groups like the informal sector, or facilitate collaborative initiatives among businesses, the public sector, and other stakeholders.

In the short term, further stakeholder engagement and research is needed. The above recommendations typically involve many stakeholders and require solid evidence of the benefits of circular economy opportunities in India. A good place to start could be engaging those stakeholders and conducting additional research, built on the findings of this report. Such initiatives would be most successful if led from within India.

CHAPTER 1 — RETHINKING VALUE CREATION: THE CIRCULAR PERSPECTIVE



CHAPTER 1 – RETHINKING VALUE CREATION: THE CIRCULAR PERSPECTIVE

The concept of a circular economy

Restorative and regenerative by design, a circular economy aims to keep products, components, and materials at their highest utility and value at all times. A circular economy is a continuous cycle that preserves and enhances natural capital, optimises resource yields, and minimises system risks by managing finite stocks and renewable flows.

In a circular economy, value creation is decoupled from the consumption of finite resources. The model distinguishes between technical and biological cycles, which rely on distinct capital-building strategies. Consumption happens only in biological cycles, where nutrients are metabolised – e.g. through composting or anaerobic digestion – and life processes regenerate the living systems, such as soil, plants, or animals, that give rise to materials and other resources. Technical cycles recover and restore products, components, and materials through strategies like reuse, repair, remanufacture, refurbishment, or (in the last resort) recycling (see Figure 3).

In a circular system, innovation and restoration increase long-term resilience. A circular economy does not just amount to adjustments aimed at reducing the negative impacts of the linear economy; it reflects a systemic shift

that creates a positive and self-reinforcing development cycle, generating business and economic opportunities and environmental and social benefits.

The notion of circularity has deep historical and philosophical origins. The idea of feedback, of cycles in real-world systems, is ancient and has echoes in various schools of philosophy. It enjoyed a revival in industrialised countries after World War II when the advent of computer-based studies of non-linear systems unambiguously revealed the complex, interrelated, and therefore unpredictable, nature of the world we live in – more akin to a metabolism than a machine.

The circular economy model arose from several major schools of thought that emerged in the 1970s and gained prominence in the 1990s. They include the functional service economy (performance economy) of Walter Stahel; the Cradle to Cradle design philosophy of William McDonough and Michael Braungart; biomimicry as articulated by Janine Benyus; the industrial ecology of Reid Lifset and Thomas Graedel; natural capitalism by Amory and Hunter Lovins and Paul Hawken; and the blue economy systems approach described by Gunter Pauli.

Circular economy as a framework for long-term prosperity in India

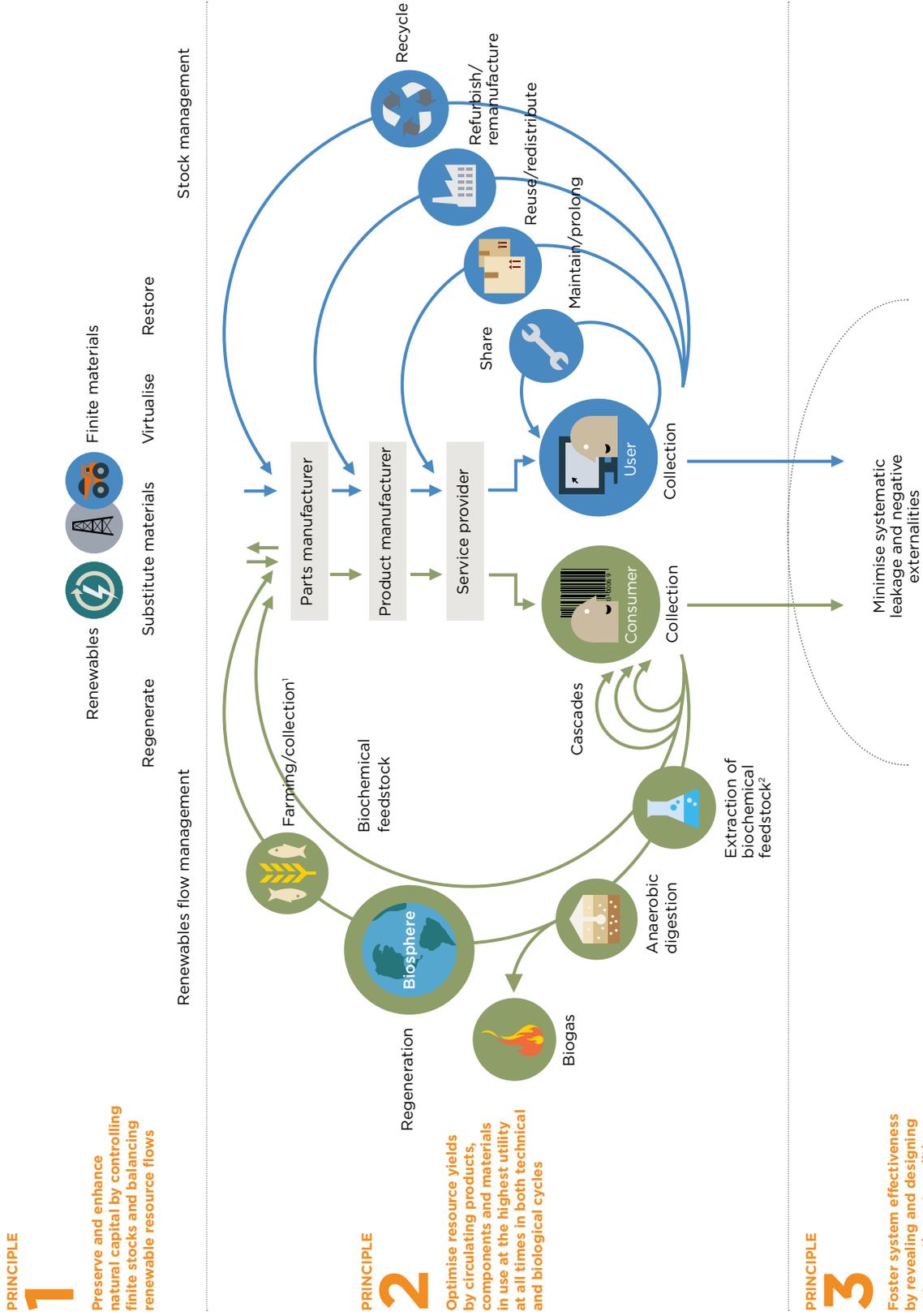
Recent initiatives by businesses, government bodies, and non-profits in India show alignment with the principles of a circular economy. These initiatives include vehicle-sharing schemes, investments in renewable energy, and programmes to train farmers to understand and adopt regenerative practices.

Several aspects of a circular economy are deeply ingrained in the habits of India's people – for example, high utilisation and repair of vehicles and distributed recovery and recycling of materials post-use. Often handled informally, these activities provide the only source of livelihood for some of the poorest parts of the

population. For example, 60% of discarded plastics are recycled in India, compared to 6% in the U.S., and 95% of this activity happens informally.

But these practices tend to happen at the very end of the value chains and amount to scarcity management strategies, with little upstream effort to enable effective recovery. As a result, much of the value is lost, compared with a system designed for circularity and value creation in the first place. Current practices also create significant negative externalities, including health risks for the wastepickers and

FIGURE 3: OUTLINE OF A CIRCULAR ECONOMY



1 Hunting and fishing
 2 Can take both post-harvest and post-consumer waste as an input
 Source: Ellen MacArthur Foundation, SUN, and McKinsey Center for Business and Environment;
 Drawing from Braungart & McDonough, Cradle to Cradle (C2C).



large volumes of low-value materials remaining in streets and dumpsites and eventually leaking into rivers and oceans.

Besides, India is changing rapidly. As the middle class expands and the Indian population gets access to better living standards, recovery activities are likely to become less attractive – unless a systematic approach is taken to professionalise them and move them up the value ladder. This development could reduce circularity in the system.

As India emerges as a powerhouse on the global stage and connects increasingly to the largely linear supply chains of global markets, economies of scale are likely to pull the country towards the same one-way model of economic growth that industrial markets embraced. This would further limit the impact of current circular practices.

Without an ambitious long-term vision of a circular economy and engagement of business, policy, and education in its realisation, India would likely pursue a predominantly linear development path, wasting value and saddled with externalities like environmental degradation and resource constraints. This could, in turn, limit India's economic development.

The circular economy model could provide a strong framework for development and a basis for setting principles to guide business innovation, policy, and education. Applying these principles would help India build on its current circular economy practices and scale them across sectors and value chains, using existing building blocks to embark on a circular development path and capture its benefits.

The principles of a circular economy

The circular economy model rests on three principles. Each addresses several of the resource and system challenges that India faces today or might face tomorrow.

Principle 1: Preserve and enhance natural capital by controlling finite stocks and balancing renewable resource flows

A circular economy enhances natural capital by encouraging flows of nutrients within the system and creating the conditions for regeneration of soil and other living systems. Whenever possible, utility is provided virtually or as a service rather than as a physical product. When resources are needed, the circular system favours technologies and processes that use renewable or better-performing resources.

The circular economy seeks to address several challenges to natural capital.

Threatened stock and variable quality of fresh water. The Indian economy, especially the agricultural sector, relies heavily on fresh water. India has significant groundwater resources, but faces pressing challenges, including droughts that affect 330 million people;¹⁵ waterborne diseases that affect 37.7 million people and cost 73 million working days every year;¹⁶ and

water contamination by sewage and agricultural runoff. Overall, 76 million people in India do not have access to safe water.¹⁷

Assuming continued economic and population growth, demand for water is expected to outstrip supply by 2020,¹⁸ a trend that climate change is likely to exacerbate.

Soil degradation. The Indian economy relies heavily on agriculture. It provides 64% of total employment in rural areas¹⁹ and contributes 17.4% of GDP.²⁰ Over half the land in India is arable.²¹

Soil degradation is a significant problem, with total annual costs estimated at more than ₹35,000 crore (US\$ 5.4 billion).²² It is estimated that 147 million hectares, or 55% of the land used for biomass production, is degraded.²³

While some degradation is natural, due for example to earthquakes and landslides, the major causes are human and include deforestation, over-grazing, and urban sprawl.²⁴ A decline in soil quality results in lower crop productivity, prompting farmers to make greater use of fertilisers, and in so doing reduce their profits.²⁵

Loss of biodiversity. India is a very biodiverse country. With over 45,000 species of plants and 81,000 species of animals, it is home to

7-8% of all recorded species.²⁶ This biodiversity underpins many ecosystem services that benefit humans.

But India also contains two of the world's most threatened hot spots: the Eastern Himalayan region and the Western Ghats.²⁷ At least 10% of India's wild flora and possibly more of its wild fauna are on the list of threatened species.²⁸

Depletion of fish stocks and degradation of marine ecosystems. India recently joined the group of largest fish-producing countries in the world, bringing to market about 9 million metric tonnes a year, just behind China.²⁹ Over 14.5 million people rely on fishing activities for their livelihood,²⁹ including 3.5 million people who fish along the 8,118 km of Indian coastline.³⁰

A number of factors, including increased demand by local and global markets and various negative externalities (e.g. from coastal development activities, agricultural run-off containing pesticides and fertilisers, and industrial and urban wastewater), increase pressure on India's fish stocks. Today 61% of the country's marine fish stocks are overexploited, while most of the remaining stocks are fully exploited, leaving little or no room for expansion.³¹

Principle 2: Optimise resource yields by circulating products, components, and materials at their highest utility at all times, in both technical and biological cycles

This entails designing for refurbishing, remanufacturing, and recycling to keep products, components, and materials circulating and contributing to the economy. Circular systems use tighter, inner loops, whenever possible, to preserve energy and economic value. These systems also optimise the reuse of products and extend usage length. Sharing models increase product utilisation. Circular systems also maximise the value of biological materials by cascading them through different applications and extracting biochemical feedstocks before they re-enter the biosphere safely to regenerate valuable resources.

As in a linear system, increasing yields is useful and requires ongoing system improvements. But unlike a linear system, a circular system would

not compromise effectiveness – which requires a fine balance between efficiency and long-term resilience.

The circular economy seeks to address several resource challenges.

Materials consumption. India's material consumption per capita has been increasing slowly, compared with other emerging economies like China, and remains low by international standards.³² In 2009 India consumed 7% of all materials used in the world, while housing about 14% of the world's population.³³

However, India's material productivity (defined as GDP per used tonne of material) is relatively low, despite improvements over the last decade, and is expected to remain behind that of high-income countries by 2030. As a result, if India maintains the economic development pace of the past few decades, it stands to more than triple its demand for resources by 2030.³⁴

Nutrient loss. The deterioration of soil due to loss of nutrients is a significant trend in India. Annual losses amount to 0.8 million tonnes of nitrogen, 1.8 million tonnes of phosphorus, and 26.3 million tonnes of potassium.³⁵ As a result, the amount of fertilisers applied to Indian fields increased sharply from 2002 to 2011 and is still at very high levels.³⁶

Waste of products and materials. India lacks reliable national data on volume of waste and its management.³⁷ But some estimates say that more than 50 million tonnes³⁸ of municipal solid waste are generated annually and project that number to reach 150 million tonnes by 2025.³⁹

In addition to unavoidable value losses, waste treatment is responsible for 124 million tonnes of GHG emissions a year (6.7% of total Indian GHG emissions).⁴⁰ Furthermore, large amounts of unprocessed waste end up in open-air dumpsites, usually near urban areas, posing major threats to human health and local environments.⁴¹

Principle 3: Foster system effectiveness by revealing and designing out negative externalities

The negative externalities of economic activity include land degradation; air, water, and noise pollution; release of toxic substances; and GHG

emissions. These impacts are seldom reported or accounted for, and their weight is borne by both ecosystems and society.

A circular economy would reveal the cost of these externalities – in other words, outline their risks and potential economic impact.[†] Furthermore, by including feedback that effectively integrates these costs, a circular system would gradually eliminate negative externalities.

The circular economy seeks to address several systemic challenges.

Noise pollution. Noise pollution is significant in Indian cities. A study found that major cities, including Mumbai, Hyderabad, and Delhi, exceeded government noise limits, due to noise from industry, transport, and construction.⁴⁴ Such high noise pollution has been linked with various health issues, especially cardiovascular disease.⁴⁵

Air pollution. Air pollution is a major issue in India. The World Bank estimated its economic loss due to reduction in welfare at 7.7% of

India's GDP in 2013.⁴⁶ The health effects are especially significant, including respiratory and cardiovascular diseases. According to the World Health Organization (WHO), outdoor air pollution caused an estimated 620,000 deaths in India in 2012, the highest in the world after China.⁴⁷

The causes of air pollution include biomass burning, vehicle emissions, and industry. Despite improvements, the levels of various pollutants in the air remain significantly above national air quality standards in most cities.⁴⁸

Greenhouse gas emissions. Per capita carbon emissions in India are significantly lower than the global average,⁴⁹ and while expected to rise, are likely to remain lower over the next 20 years.⁵⁰ However, in absolute terms, due mainly to greater coal combustion, India's CO₂ emissions more than tripled between 1990 and 2014 and are the third highest in the world.^{51,52} As part of the 2015 Paris Agreement on climate change, India committed to reduce the GHG emission intensity of its GDP by between 33% and 35% by 2030 compared to 2005 levels.⁵³

[†] A number of organisations, including businesses, the public sector and other institutions, have already been developing methods to incorporate natural capital considerations in decision-making. For example, the Natural Capital Coalition, a global multi-stakeholder collaboration bringing together over 200 global initiatives and organisations, recently launched the Natural Capital Protocol.⁴² This framework builds on existing techniques to identify, measure, and value natural capital in the context of business decisions. The coalition piloted the protocol with more than 30 businesses, including the Indian conglomerate Tata and several corporates with significant operations in India.⁴³

CHAPTER 2 — WHAT A CIRCULAR ECONOMY COULD LOOK LIKE IN INDIA



CHAPTER 2 — WHAT A CIRCULAR ECONOMY COULD LOOK LIKE IN INDIA

India faces profound choices about its development path. This report outlines opportunities to shape India's future and build a regenerative, restorative economic model that creates long-term value and minimises negative externalities. These circular economy opportunities have been developed in three focus areas: cities and construction, food and agriculture, and mobility and vehicle manufacturing.

The selected focus areas are crucial for the Indian economy and population in several ways and come with significant potential for circularity. Representing more than two-thirds of spending by urban as well as rural households in India,⁵⁴ they are critical to meeting the basic human needs of housing, food, and mobility. Agriculture and the construction industry are the two largest sources of employment in India, together accounting for around 60% of the working population^{55,56} and are responsible for the vast majority of India's raw materials consumption.⁵⁷ Additionally, construction and vehicle manufacturing are expecting huge growth over the next decades.^{58,59} Overall, the three focus areas account for more than 30% of India's gross value added.⁶⁰

To explore the impact of adopting circular economy principles in the three focus areas, the analysis investigated two development scenarios in 2030 and 2050 – the current development path and a circular development path. Both scenarios take into account projected increases in population, urbanisation, and income and the associated growing needs for housing, food, and mobility.

The current development path reflects expected trends and technological development. This path would reduce costs and increase convenience but would not make system-level changes.

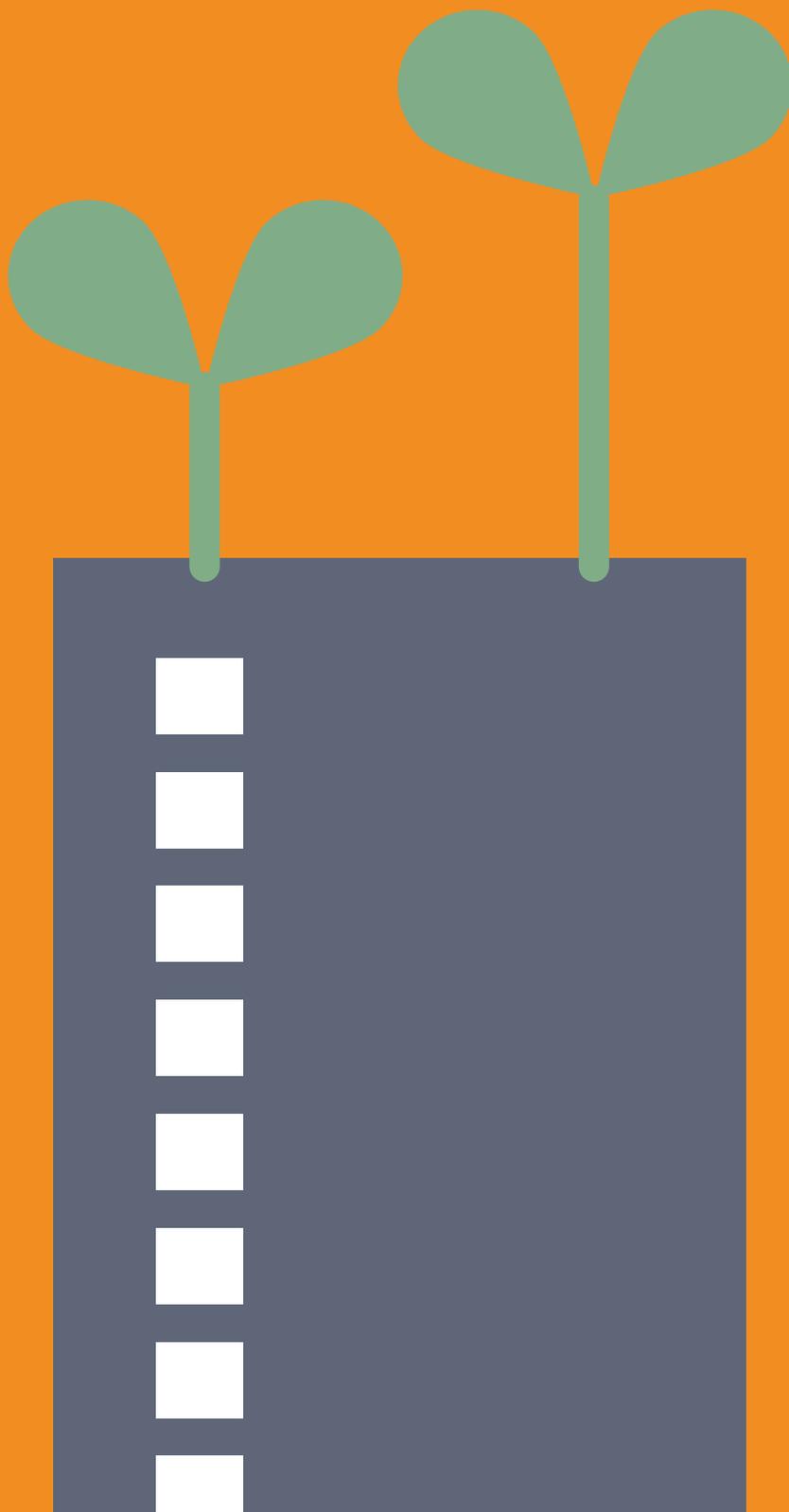
The circular development path reflects a system-based approach that would take full advantage of circular economy opportunities and leveraging readily available and emerging technologies.

The high-level modelling comparing the two scenarios, supported by previous research and analyses by the Ellen MacArthur Foundation and others, points to the conclusion that India would achieve better economic, environmental, and societal outcomes by choosing a circular development path.

Taking a circular development path would require making systemic shifts, not just making tweaks related to individual opportunities. Therefore, consideration of pursuing the opportunities described individually in the following needs to take their interconnectedness into account. Several opportunities reinforce or accelerate the impact of others, so capturing maximum value would require considering this compounding effect. Additionally, all three focus areas studied are part of the overall economic system and involve significant interactions.

Additional opportunities exist in other sectors of the Indian economy and it would require thorough investigation to identify these opportunities and quantify the associated benefits.

Cities and construction



CITIES AND CONSTRUCTION

By 2050, 60% of India's population will live in urban areas – up from about 30% today.⁶¹ Urbanisation is happening at an unprecedented pace. Growth is so rapid that 70% of the building stock that will be used in 2030 is yet to be built,⁶² and choices made today will determine India's mid- to long-term development. Applying circular economy principles to developing this vast amount of infrastructure and building stock could create annual benefits of ₹4.9 lakh crore (US\$ 76 billion) in 2050, compared with the current development path, together with environmental and social benefits.

In India, as elsewhere, cities play a critical role in economic growth. Urban centres are major consumers of energy and resources. Globally, cities use approximately 75% of natural resources and produce 75% of carbon emissions.⁶³ Currently accounting for 60% of India's GDP, urban centres are expected to generate 75% of GDP by 2030.⁶⁴

Cities are attractive because they offer employment opportunities and the prospect of enhanced quality of life, but growing populations exacerbate pressure on their infrastructure. Providing access to clean water, sanitation, waste management, effective transport flows, and affordable housing presents challenges that India must address to achieve inclusive economic growth.⁶⁵

The Indian construction sector is poised to become the third largest globally.⁶⁶ Already creating more than 8% of GDP, this highly fragmented and largely informal sector will play an increasingly important role as the population and, with it, demand for buildings expand.⁶⁷ The affordable housing shortage is expected to reach about 38 million units by 2030.⁶⁸ To meet the needs of its rapidly urbanising population, India must build 700-900 million square metres of new commercial and residential space every year – the equivalent of what now exists in Chicago.⁶⁹

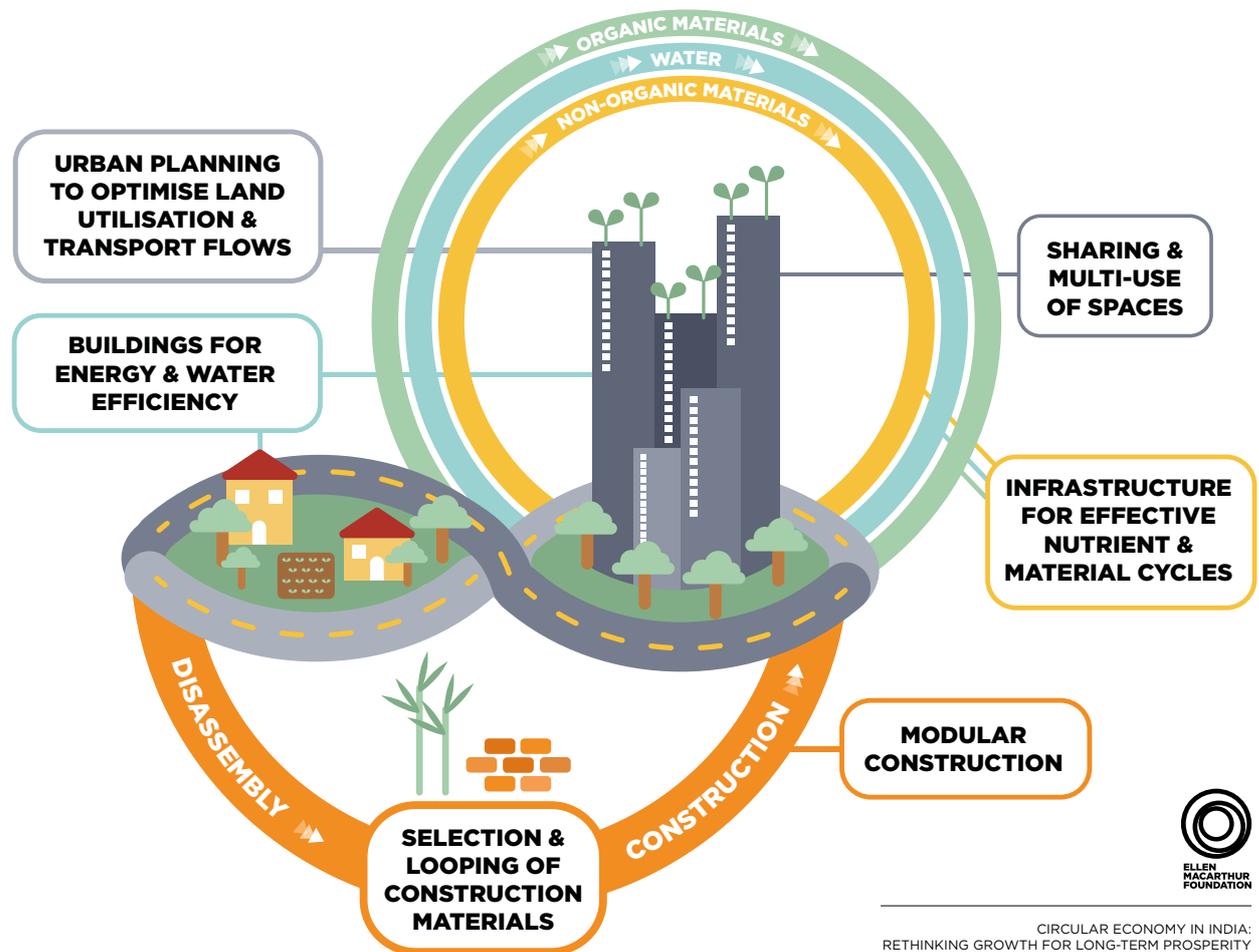
The construction industry offers significant opportunities to gradually decouple economic growth from the consumption of finite materials and non-renewable energy. The global construction industry is the single largest consumer of resources and raw materials, and in India, construction accounts for about 20% of total material demand.^{70,71} Additionally, and in line with global averages, construction and demolition waste is significant, generating about one third of India's total solid waste.⁷² The Indian

building industry consumes almost 34% of the country's total energy, making it one of the largest emitters of greenhouse gases.⁷³

Buildings are long-term assets typically lasting more than 50 years. Over 80% of the total energy related to a building is consumed during its use – mostly for heating, cooling, lighting, and appliances – while manufacturing, transportation of materials, construction, and maintenance account for the rest.⁷⁴ Energy consumption by residential buildings is predicted to rise more than eight-fold by 2050, with annual electricity use per household predicted to increase from 650 kWh in 2012 to 2750 kWh by 2050.⁷⁵ Transforming building design and rethinking the resources used in construction can contribute to the creation of resilient cities, decoupled from the consumption of virgin, non-renewable materials.

Focused government initiatives suggest that the time is ripe for Indian cities to embrace circular economy approaches. Initiatives by the Indian government, such as the Smart Cities Mission, development of industrial corridors, the Swachh Bharat Mission, and city renewal schemes like the 500 AMRUT cities, are accelerating investment in the construction of urban infrastructure. Research by the McKinsey Global Institute indicates that India needs to invest ₹77 lakh crore (US\$ 1.2 trillion) in city infrastructure by 2030.⁷⁶ Developing this infrastructure following circular economy principles can avoid getting locked into resource-ineffective systems in the long term.

As new building technologies and business models emerge and reach scale, urban planning should embrace circular economy approaches. Circular economy opportunities could help India create high-quality spaces where people would live, work, and play.

FIGURE 4: CIRCULAR ECONOMY IN INDIA FOR CITIES AND CONSTRUCTION

CIRCULAR ECONOMY IN INDIA:
RETHINKING GROWTH FOR LONG-TERM PROSPERITY

SIX OPPORTUNITIES TO SHAPE INDIAN CITIES AND THE CONSTRUCTION INDUSTRY

A broad range of circular economy opportunities exists for India to consider when shaping the future of its cities and constructing housing and commercial spaces until 2050. This research identified six major opportunities. To realise the full value identified in the analysis, these opportunities need to be implemented in concert and as part of a strategy that takes into account the whole system (see Figure 4).

Opportunities in cities

In the overall system of a city, many sub-systems interact. By adopting circular economy approaches, India could connect these sub-systems to provide thriving, liveable cities designed around citizens. Three main opportunities have been identified for cities.

Urban planning to optimise land utilisation and transport flows. Systemic approaches to urban planning integrated with the application of circular economy principles to food and mobility systems can create more resilient

cities. Compact and diverse city typologies optimise land use and can offer economies of scale for circular models. While existing megacities would have to retrofit systems to reverse inefficient land use and infrastructure, growing smaller cities have the most opportunity to plan development from the start to avoid getting locked into poor land use and transport systems.

Planning for compact growth by building vertically in appropriate areas and integrating mixed use of land with a multimodal transportation system to locate people along transport routes frees up land for urban green spaces and affordable housing. This could enable growing cities to avoid getting saddled with poor traffic management, declining air quality, and sprawling development around the city periphery. Indian cities have low average floor area ratios (FAR, the ratio of a building's total floor area to the size of the land on which it sits), compared with cities globally. Building vertically around transit nodes to connect places of residence, work, and recreation would offer an opportunity to prevent urban sprawl and reduce travel distances.⁷⁷

India could thus free up land for affordable housing and green spaces. Curitiba, Brazil shows how land use planning and transport links can transform the urban environment. Placing controls on urban sprawl, introducing pedestrian-only areas, and implementing an affordable public transport system have reduced fuel consumption by 30% and lowered ambient air pollution, compared with other Brazilian cities.^{78,79} Prohibiting the development of land in areas susceptible to flooding has kept land free for urban green spaces and reduced risks to the public.

Through the Smart Cities Mission, India is beginning to see renewed efforts in urban planning. Several Indian cities are gaining international recognition for their efforts to transform into smart cities.⁸⁰ Some of the activities planned for Pune, for example, include redesigning junctions in order to improve traffic flow, dedicating more space to pedestrians, and increasing non-motorised transport options.⁸¹

Infrastructure for effective nutrient and material cycles. Innovative solutions for wastewater and solid waste management can close loops to make the underlying resource streams more effective, keeping nutrients

and materials flowing through the system, rather than being dumped into landfills or leaked into the environment. Approaches that incorporate effective collection systems to separate biological nutrients from technical materials maximise value recovery and enable regenerative material flows.

Access to sanitation is generally widespread in Indian cities, but the quality of these services is often poor.⁸² Where water supply exists, as much as 50% of water is lost during distribution due to leaking pipes and poor water management.⁸³ Almost 70% of sewage generated in urban India remains untreated, contaminating environments and water bodies and contributing to the spread of disease and leakage of organic nutrients.⁸⁴

As urban populations grow, developing water and wastewater infrastructure that creates effective cycles of water and nutrients can avoid dependence on high-energy and chemical-intensive treatment processes, reduce treatment costs, and improve the health of citizens. Innovative approaches to water management and nutrient flows in urban areas, adaptable to local community needs, are emerging, such as that offered by Biopolus Technologies (see *Biopolus: The future of urban water systems?*).

BIOPOLUS: THE FUTURE OF URBAN WATER SYSTEMS?

Redesigning the urban metabolism encourages cities to invest in effective water management solutions that close water, food, nutrient, and energy loops while delivering social benefits. Biopolus offers an integrated network of water treatment facilities (metabolic hubs) in aesthetically appealing multi-functional buildings that can provide sanitation solutions for informal settlements, luxury residential communities, and industrial parks alike.

Each hub can serve 5,000-50,000+ people. The hubs use innovative Metabolic Network Reactor (MNR) technology in a controlled, bio-engineered process to tailor water output for specific uses, including irrigation, industrial processes, and potable water.

The hubs occupy as much as 60% less land, save up to 35% on operating cost compared with traditional solutions, and can be installed with minimal disruption to local residents. The hubs can be designed in modules to provide functions of the community's choosing, such as water reuse, energy or materials recovery, bathroom blocks, laundry facilities, and even food production.

Coupled with the Biopolus Aero.Green aeroponic food growth module that uses a unique method of production in a light-weight and mobile system, the hubs can support the provision of healthy, nutritious food where water is scarce, space limited, and the population large. The system uses an atomised nutrient solution to control nutrient content and minimise water use, producing plants with aerated root systems that are less susceptible to infection by pests and disease.



The treatment of solid waste in Indian cities is also a major stumbling block. The informal sector can provide a starting point for developing effective reverse logistics to help create material flows in cities, whilst addressing social challenges. Informal sector workers typically recover non-organic waste, collecting high-value items, but leave low-value materials and organic matter largely discarded and untreated. Informal recycling activities handle a total of 4.7 million tonnes of plastics per year, while only 0.2 million tonnes are collected and recycled via public waste collection systems.⁸⁵

The role of the informal sector in material flows is seldom recognised formally. Wastepickers work in hazardous conditions without access to safety equipment or health care.⁸⁶ India has made some advances in incorporating wastepickers into the formal waste management system of communities and into efforts to include organic waste in collections. In Pune, for example, the workers' unions for wastepickers are collaborating with municipalities to provide contracted waste management services for a fee. The wastepickers make door-to-door collections and separate organic and non-organic materials for composting, conversion to energy, or recycling. The user fee has boosted wastepickers' incomes, and collecting waste closer to the point of generation has improved the quality of recycling and waste management for local residents. The city is saving an estimated ₹18 crore (US\$ 2.8 million) per year.⁸⁷

Developing the skills of the workforce, in parallel with developing appropriate infrastructure, provides an opportunity to create social benefits, while reducing material demand and economic losses.

But India needs more systemic solutions to foster efficient nutrient and material cycles. Organic and non-organic waste needs to be cycled separately to recover full value. Organic materials can be treated in biorefineries that employ a range of techniques, including thermal treatment and biological processes, to produce high-value chemicals, fertilisers, and energy. This can include composting and anaerobic digestion (see p. 44).

For non-organic waste, systemic initiatives can provide inspiration, for example, the New Plastics Economy Initiative.⁸⁸ The initiative is collaborating along value chains to close loops on plastic packaging. Effective collaboration among suppliers, manufacturers, retailers, users, governments, and the informal sector could improve the management of nutrient and material stocks and flows to see value captured and shared more equitably.

Sharing and multi-use of spaces. Flexibility of spaces is key to maximising the asset utilisation rates of buildings and can improve access and affordability for customers. Digital applications can facilitate the sharing of spaces and allow utilisation of spaces for multiple functions throughout the day.

India is predicted to have the largest and youngest employable population in the world by 2020, with an average age of 29.⁸⁹ This demographic is increasing the popularity of co-working spaces. Small businesses and entrepreneurs see these spaces as affordable options that also offer networking opportunities.

Furthermore, about 15% of India's offices currently stand vacant.⁹⁰ Utilising this capacity would decrease the need for new buildings. Digital apps are enabling both the management and the accessibility of such spaces. The Binary Workshop, a technology agency in Chennai, has developed TheWorks@pp, a software platform for managing such spaces. The app also enables users to manage their membership, book spaces, and see events. It reduces operational costs by automating administrative tasks.

Sharing platforms also enable flexible spaces to be made available to several users and multiple functions over the course of a day. Designing buildings for easy reconfiguration to accommodate several functions optimises the use of urban spaces.⁹¹ This idea is not new. For example, Manek Chowk, a market square in Ahmedabad, transforms from vegetable market to jewellery market and then to food market over the course of one day. This idea can be applied to existing underutilised spaces. The US start-up Spacious, for example, makes use of restaurants that are empty by day to provide working and meeting rooms.⁹²

A familiar example of sharing residential space, Airbnb has demonstrated the success of peer-to-peer sharing enabled by technology and challenged the conventional hotel model, by letting homeowners profit from their underutilised spaces. Some Indian states, including Gujarat, are supporting such sharing by updating policy to support homestays.⁹³

The idea of co-living is similarly gaining momentum, with companies like CoHo offering luxury shared living spaces. CoHo has more than 20 properties across New Delhi, with over 300 beds occupied, and plans to scale up to more than 1,800 spots. CoHo gives residents access to an app, where they can get free assistance from an online concierge and offers from partner brands.⁹⁴

Opportunities in construction

Current growth rates suggest that, by 2020, the Indian construction industry will be the greatest material-consuming sector in India.⁹⁵ Circular economy principles applied to design could mitigate against supply disruptions and volatile resource prices by decoupling construction from GHG emissions, non-renewable energy

use, and finite resource consumption. Designing buildings that apply circular economy principles to construction, operation, and end of use could make buildings durable, yet adaptable spaces that produce, rather than consume, energy. Three main opportunities have been identified for the Indian construction industry.

Buildings designed for energy and water efficiency. The significant construction activity yet to happen in India provides an opportunity to design buildings for energy and water efficiency and to avoid getting locked into intensive long-term use of these resources. Passive heating and cooling, use of insulation, optimisation of natural light, and efficient lighting systems offer solutions for comfort that are adaptable to local climate conditions.

Coupled with renewable sources, these solutions could create net zero or even energy-positive buildings. One example is the Indira Paryavaran Bhavan building (see *India's first net zero energy building*). Innovations are making the integration of renewable energy solutions into building construction easier. For example, roof tiles that generate solar electricity, such as those developed by Tesla Solar Roof, can make the addition of solar panels redundant.

Arup has developed SolarLeaf panels that can be used for building cladding and shading devices. The panels harvest, distribute, store, and use solar thermal heat on site. In a closed-loop system, these panels use nutrients from wastewater and can support the cultivation of micro-algae for food.⁹⁶

India faces the prospect of severe water scarcity and water pollution (see p. 22). Including water-efficient fittings, rainwater capture, and greywater cycling systems in building designs from the start can reduce water demand to alleviate pressure on the water supply, create regenerative wastewater treatment processes and better manage water locally. For example, the CII Sohrabji Godrej Green Business Centre in Hyderabad has achieved 35% potable water savings through rainwater harvesting and on-site water recycling.⁹⁷

The introduction of the Energy Conservation Building Code (ECBC) and the adoption of green rating systems like the Green Rating for Integrated Habitat Assessment (GRIHA) mark some progress toward resource-efficient buildings in India. While not the end goal in a circular economy, scaling and adapting energy conservation solutions specific to India would be a necessary step in the transition reducing total energy demand and making meeting energy needs with renewable energy sources easier.

For example, the Torrent Centre in Ahmedabad has maximised natural ventilation with passive downdraft cooling systems, providing a comfortable indoor temperature without extensive use of air conditioning in a hot, dry climate. The system has achieved energy savings of 64%, and the electricity savings over 13 years of operation have recouped the entire cost of the building.^{98,99}

Consideration of India's five varied climatic zones at the design stage could optimise the use of water and energy in buildings for

local conditions. Where necessary to provide comfort, small, decentralised, demand-driven air conditioning systems can reduce pipework and space needed in the building, compared with conventional systems.¹⁰⁰ Given the trend towards using air conditioning, scaling passive design and renewable energy sources for all commercial and residential buildings could significantly reduce demand for energy and water.

INDIA'S FIRST NET ZERO ENERGY BUILDING

The Indira Paryavaran Bhavan office building houses the Ministry of Environment, Forests, and Climate Change (MoEFCC) on seven floors in New Delhi. The building, reportedly the first net zero building in India, has achieved net zero energy consumption through a two-pronged approach – minimising energy demand and meeting the demand with renewable energy.

Building design features minimise energy and water consumption for total energy savings of 40% and water savings of 55%. The building has the largest rooftop solar system among multi-story buildings in India, with an installed capacity of 930 kW peak solar power supplying the total energy needed by the building.

The configuration and orientation of the building optimise ventilation by separating blocks with connecting corridors built around a large central courtyard. Chilled beam air conditioning reduces energy consumption by 40%, compared with a conventional system, by cooling the air via water in pipes throughout the ceiling. Energy-efficient lighting further reduces energy consumption, and even the passenger elevators generate energy during use.

Water-efficient fittings, rainwater capture, and the reuse of treated water for plant irrigation and cooling systems reduce water demand. Sewage is treated on site and the resulting clean water irrigates vegetation around the building, meaning that no water escapes from the site.

Modular construction. Industrialised production, modularisation, and standardisation of components can cut the time, cost, and materials consumption of construction, enabling rapid building of affordable housing and supporting the construction of high-quality incremental housing. Constructing modular buildings in layers enables the reconfiguration of spaces and reduces functional obsolescence and maintenance costs by making buildings adaptable to user needs and evolving urban structures. Seamless, continuous digital processes can support these methodologies from design to construction to operation.

Modular and pre-fabricated building is not a new concept in India, but wider application of the idea as the construction sector grows could meet building demand in both the commercial and the residential sectors. Digital technologies like building information modelling (BIM) can

support the transformation of construction techniques (see *The circular building*). BIM can also collate data during building operations to facilitate monitoring, enable preventive maintenance, and better inform upgrades and modifications of systems and components.¹⁰¹

The Broad Group, a Chinese contractor specialising in modular construction, has increased efficiency in production, installation, and logistics six to ten times higher than conventional construction, with almost zero materials waste and 40% lower total cost of construction. The Broad Group has also demonstrated impressive time savings by constructing a 57-story building in just 19 days.¹⁰²

To meet the government's ambition of affordable housing for all by 2022, India could leverage modular construction techniques to build durable, low-cost homes rapidly, while

reducing materials consumption. WorldHaus in India is using modular and prefabricated components to create affordable housing solutions. Building its first prototype house in Chennai in 2011, the company tapped prefabricated and modular systems to construct permanent housing that uses 20% less cement and sand and 80% less construction steel than traditional Indian masonry construction. WorldHaus' modular panels are insulated to offer comfort and decrease the summer indoor temperatures by around 8°C.¹⁰³

Selection and looping of construction materials. Selecting regionally appropriate, renewable, non-toxic materials and retaining construction materials at their highest value reduces demand for non-renewable, virgin materials and hence reduces GHG emissions and energy use. Leveraging tracking technologies, such as BIM or radio frequency identification

(RFID), can help predict materials performance, support design for disassembly, and enable preventive maintenance. These technologies also support the use of buildings as materials banks – identifying materials for reuse after building use ends and capturing value by keeping materials in tighter loops.

India's cement industry alone is responsible for approximately 7% of the country's GHG emissions.¹⁰⁴ As building demand increases, replacing conventional construction materials like those used to make concrete and bricks with locally available, recycled or renewable resources could reduce GHG emissions, energy use, and consumption of finite materials.

New materials that offer economic advantages can support the provision of affordable housing, while reducing the environmental impact of extracting and processing materials, such as sand and aggregates.

THE CIRCULAR BUILDING

Arup's circular building project, launched in September 2016, used technology to maximise utilisation of components and materials. Arup designed the building for disassembly, using non-toxic and pre-fabricated components that can easily be taken apart.

Arup applied BIM to enable the building to function as a material bank. The 3D BIM model for the building provided transparency into building material composition, and digital technology tagged all items, from window frames to individual fittings, each with a unique QR code containing information needed for reuse.

This improved access to information helped multiple stakeholders collaborate more efficiently on building design, construction, and operation and enabled Arup to contract with suppliers to take back materials after their use.



For example, bamboo is fast growing, readily available almost everywhere in India,¹⁰⁵ and able to grow in diverse conditions. India is the second largest bamboo producer, after China.¹⁰⁶ Bamboo houses can cost 60% less than concrete houses and be built in modules for adaptability.¹⁰⁷

Engineered clay also offers opportunities to replace resource-intensive materials. Wienerberger is making economical, perforated clay bricks at scale in India, optimising the use of clay from non-agricultural land. These bricks offer an alternative to concrete that uses up to 15% less material, takes less energy to produce, and can be recycled after use.¹⁰⁸

Recycling of construction waste also offers an opportunity to reduce consumption of materials. Indian urban areas generate significant construction and demolition waste, estimated at 531 million tonnes in 2013 by the Centre for Science and Environment.¹⁰⁹ India could realise value, as well as economic and environmental benefits, by finding uses for these materials that would otherwise go to landfills or get dumped in the streets. The processing of recycled aggregates, for example, generates 40% less GHG emissions than the processing of virgin aggregates.

The significant volumes of waste produced by the agricultural sector can be utilised in building materials to reduce waste and capture value. For example, the 24 million tonnes of rice husks discarded each year in India¹¹⁰ have many uses in construction, including as binders and in building panels, brick production, and thermal insulation. For example, 'Green Wood', a particulate board that is fungus resistant and waterproof, was recently developed in India and could be scaled to provide an alternative to soil bricks.¹¹¹

ModRoof, based in Ahmedabad, uses agricultural waste to provide modular roofing, mainly in rural areas and informal city settlements, for affordable and durable improvements to comfort. Technology, such as BIM, stores information on products and components (e.g. composition and instructions for post-use treatment) to make reusing building components and recycling materials easier and tracks and traces materials across the supply chain to facilitate information sharing (see *The circular building*).

POTENTIAL DEVELOPMENT PATHS

The outcome of decisions made about pursuing these opportunities will lead India down different development paths with widely varying environmental, economic, and social outcomes.

The following outlines two of the many potential scenarios. These are not intended as projections, but as estimates of the order-of-magnitude impact of the development paths. For a detailed comparison of the scenarios, see Appendix A.

Current development scenario. This path would see opportunities seized piecemeal and with varying impact. Urban planning would likely embrace limited and disconnected improvements to address urban sprawl, traffic congestion, and air pollution in a context of unprecedented growth.

Separation and collection of solid waste would improve, and the provision of wastewater treatment would increase, but waste management optimisation would not amount to systemic solutions minimising consumption of finite resources and would remain inherently end-of-pipe. New construction methodologies and greater efficiency in buildings would reduce energy and water use compared with buildings today, but would fall short of initiating system-level change and capturing the associated benefits. Cost benefits would be limited as best practices are not adopted at scale.

Circular development scenario. This scenario would reduce per capita demand for energy, water, and virgin, non-renewable resources, cutting costs and contributing to an enhancement of the natural capital that will be relied upon to sustain the growing population in the long term. A systemic approach would be taken to urban planning, one that considers the locations of residential and commercial areas and optimises transport patterns to create thriving, liveable, urban environments that optimise land use.

Effective infrastructure to collect and treat waste and wastewater would create systems that include current informal workers in closing material and nutrient loops to address waste issues, capture value, and create positive social impact. Scaling up the use of recycled and renewable materials in construction would reduce the consumption of virgin, non-renewable resources and the energy needed to extract and process them. Building design would look to minimise the consumption of energy and water and meet energy demand using renewable sources.

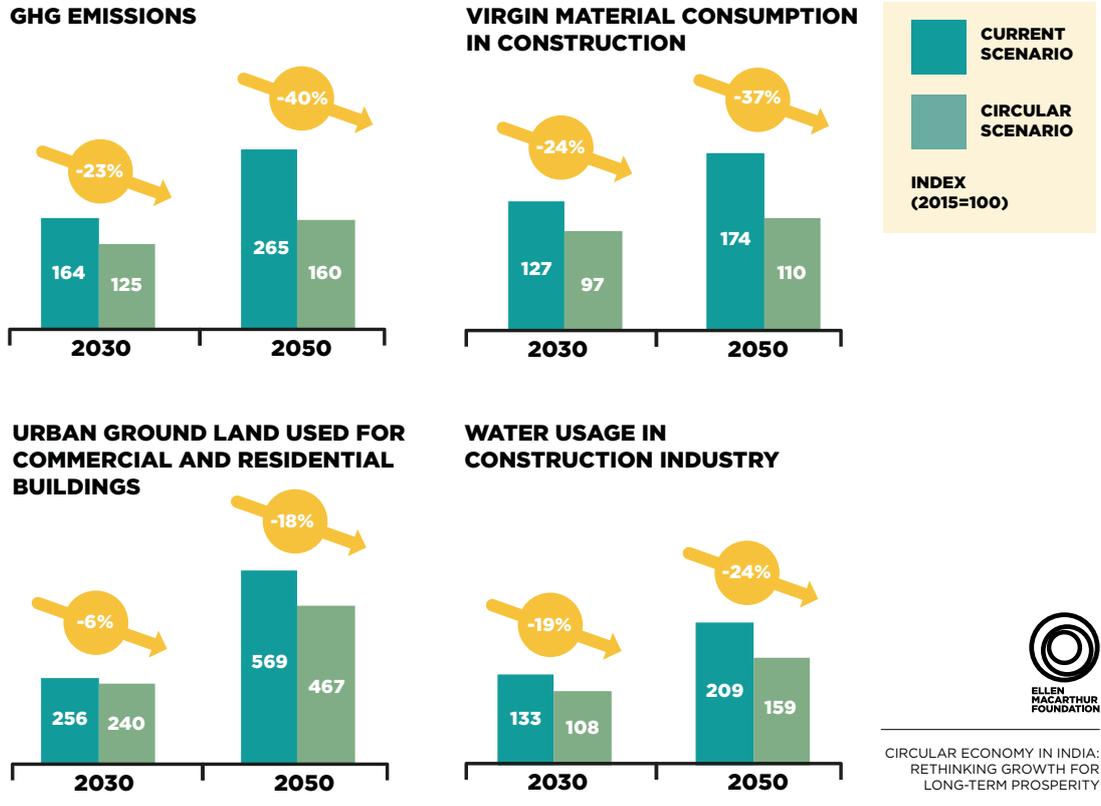
Quantified benefits

Overall, following a circular economy development path would generate annual benefits of ₹4.9 lakh crore (US\$ 76 billion) in 2050, compared with the current development path. Resource use in the construction of new buildings would also fall, with 37% less virgin,

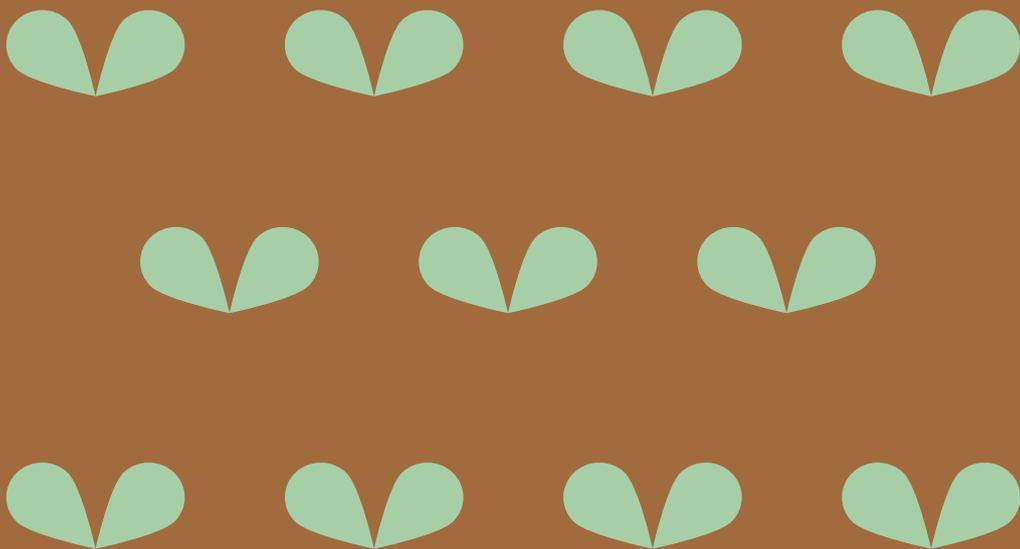
non-renewable materials needed, 24% less water consumed, and 18% less inner city land used in the circular scenario compared with the current development scenario. Following the circular

path would also reduce negative externalities, with GHG emissions in the built environment (construction of buildings and energy use for cooling) 40% lower (see Figure 5).

FIGURE 5: COMPARISON OF POTENTIAL DEVELOPMENT PATHS (CITIES AND CONSTRUCTION)



Food and agriculture



FOOD AND AGRICULTURE

Employing half of the working population and using 61% of the land, the agricultural sector is essential to the Indian economy.¹¹² Growing food demand and environmental challenges associated with climate change, land degradation, and biodiversity loss are increasing pressure on the system. Applying circular economy principles to the development of the Indian food system could create annual benefits of ₹3.9 lakh crore (US\$ 61 billion) in 2050; reduce GHG emissions, water usage, and environmental degradation; and play a vital role in securing the long-term food supply.

The agricultural system is crucial to the Indian population and economy. With some 857 million people living in rural areas, India houses the world's largest rural population,¹¹³ and agriculture is the principal means of livelihood for 58% of rural households.¹¹⁴ India's farm output ranks second in the world;¹¹⁵ and the country is emerging as a global exporter of agricultural products, having become the world's sixth largest net exporter of those products in 2013.¹¹⁶

The Indian agriculture sector faces challenges in feeding a rapidly expanding population under increasingly difficult environmental constraints. Small farms are the main providers of food and nutritional security but have limited access to technology, credit, capital, and markets¹¹⁷ so their productivity and income levels remain low and variable.¹¹⁸ In addition, agricultural production faces serious environmental constraints associated with land degradation, water scarcity, and an increasing number of extreme weather events, which are expected to worsen.¹¹⁹ Supply constraints caused by the degradation of natural capital and instability in the global financial system, coupled with increasing food demand from a growing population with increasing average per capita calorie intake, suggest that India will have difficulty meeting its long-term food demand.¹²⁰

India faces profound choices on the future of its food and agricultural system. On the one hand, development could follow a largely linear path focused on short-term efficiency gains, which – while important – would likely lead to increasing specialisation and intensification, high levels of food waste, negative environmental externalities, and unhealthy outcomes for the population.

On the other hand, a systemic approach based on circular economy principles could help build a value-preserving model that would be regenerative, resilient, non-wasteful,

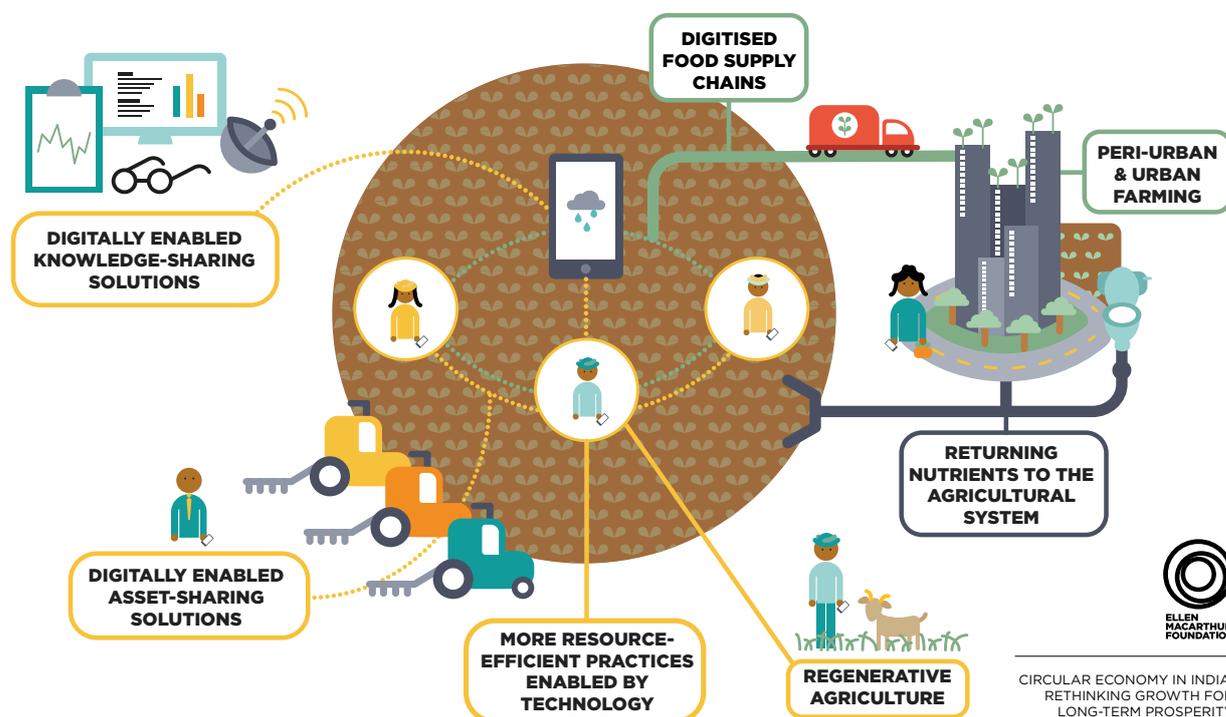
and healthier. Tapping six circular economy opportunities, this system would increase quality of life for the rural population, reduce negative environmental externalities, increase resilience to climate change, and provide long-term food security for India.

SIX OPPORTUNITIES TO SHAPE THE INDIAN FOOD AND AGRICULTURAL SYSTEM

A broad range of circular economy opportunities exists for India to consider when shaping the future of its food system and agricultural activities until 2050. This research identified six major opportunities. To realise the full value identified in the analysis, these opportunities need to be implemented in concert and as part of a strategy that takes into account the whole system (see Figure 6).

By capturing these opportunities, India could build a food and agricultural system that leverages the current small-farm structure to create a network of farmers, symbiotic in their practices and committed to regenerative approaches. Digital solutions, asset- and knowledge-sharing, and closed nutrient loops can optimise the system as a whole and generate value for households and farmers.

Regenerative agricultural production. A regenerative agricultural system preserves the integrity of the natural system, phases out toxic materials, and minimises nutrient leakage. The system uses practices like crop rotation and cover cropping and minimises tillage to retain natural capital. It often combines livestock with crop production to create additional nutrient loops.

FIGURE 6: CIRCULAR ECONOMY IN INDIA FOR FOOD AND AGRICULTURE

Current industrial agricultural practices, as they exist in most high-income countries, face major risks, including degradation of natural capital, vulnerability to climate change, volatile input costs, and the resulting long-term pressure on yields.¹²¹ By contrast, regenerative agriculture, based on principles such as retaining soil health, minimising the use of external inputs (especially pesticides and synthetic fertilisers), cycling nutrients locally, embracing synergies (e.g. combining crops and livestock), and preserving natural capital, avoids these risks and reduces negative externalities.¹²²

In India, more extreme heat and frequent droughts are expected to reduce crop yields significantly over the coming decades.¹²³ Regenerative agricultural practices can build ecological resilience to these changing climate conditions¹²⁴ and other environmental shocks (e.g. outbreaks of pests and disease)¹²⁵ while increasing yields for farmers.¹²⁶

Regenerative practices also come with additional benefits. They can help mitigate climate change by increasing the amount of carbon stored in soils and reducing the need to apply fossil fuel derived synthetic fertilisers.¹²⁷ Minimising tillage avoids the release of carbon from the soil and the crop burning that creates local air pollution and contributes to smog in cities hundreds of kilometres away.¹²⁸

Regenerative agriculture is already gaining momentum in India. Organisations like INORA, Kalpavruksha Farm, Organic India,

and Govardhan Ecovillage are applying regenerative practices at different scales and report increasing yields, health, and income. Farmers in some of India's poorest regions are seeing record rice yields, thanks to regenerative practices.¹²⁹ The northeastern Himalayan state of Sikkim is now growing 100% organically, after spending some 13 years converting 75,000 hectares of land to organic agriculture. The effort has increased farmers' income by 20% and avoided the deterioration of human health and degradation of the environment that other states are experiencing.¹³⁰

Experience shows that regenerative practices can succeed at large scale. Leontino Balbo, CEO of Brazilian sugar producer Native, shifted his whole operation from a traditional, linear model to a regenerative model that is highly productive and profitable. Today, Native is Brazil's largest sugar-cane producer, cultivating over 20,000 hectares and realising profits of US\$ 10 million. Balbo claims that regenerative practices deliver many benefits, including higher crop yields and productivity, improved soil fertility, fewer pests, more biodiversity, lower production costs, better working conditions (thanks to less exposure to toxic pesticides), higher water quality, and lower water use.¹³¹ Other examples show that a combination of different agricultural products can realise value by creating effective local nutrient cycles (see *The rice-duck farm*).

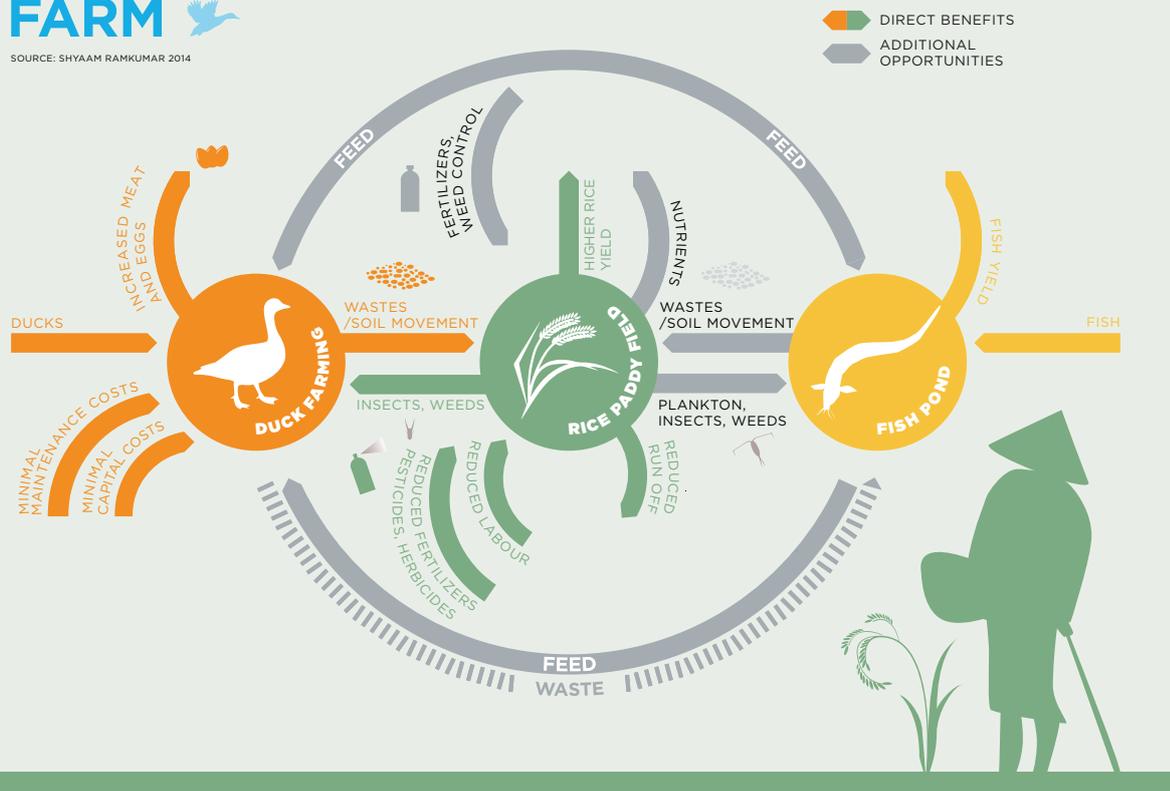
THE RICE-DUCK FARM

Takao Furuno, a Japanese farmer, has developed a duck/rice/fish farming system that avoids using lots of fertilisers and pesticides in growing rice and produces a wide range of additional food products.¹³² This system has boosted the farm's rice yields 20-50% beyond industrial rice systems' yields, and gross income from the six-acre farm sometimes exceeds the income of an American 600-acre rice farm.¹³³

The complex system required careful planning. After the rice seeding, ducklings go into the paddies to feed on insects that attack young rice plants. Then fish and paddy weed are introduced. The paddy weed fixes nitrogen and provides food for the fish and the ducks. The nitrogen and the droppings from the fish and ducks provide all the nutrients that the rice needs.¹³⁴ The ducks oxygenate the water and encourage the roots of the rice plants to grow, while digging up weeds with their feet.¹³⁵

THE RICE-DUCK FARM

SOURCE: SHYAAM RAMKUMAR 2014



More resource-efficient agricultural practices

enabled by technology. Sophisticated agricultural approaches that leverage IT, big data, remote sensing, and real-time environmental data can optimise returns, while reducing environmental externalities. Non-digital technological solutions, such as systems to improve irrigation, can also create value.

Digital technology is changing farming by enabling increasingly sophisticated precision agriculture approaches, as well as whole-farm management through the emergence of integrated data platforms. Precision farming

can increase the efficiency of conventional agricultural systems but has proven especially effective combined with regenerative practices.¹³⁶

Conventional agricultural systems are already using these technologies widely. For example, US-based OnFarm has developed an internet-of-things service that combines comprehensive farm hardware technologies on a single platform. The platform provides a farm management tool that displays and analyses data from many sources in a single application for near-real-time

decision-making.¹³⁷ The tool enables optimal fertiliser and pesticide application and irrigation practices that reduce waste and leakage.

In India, small farm size limits the feasibility of such solutions, particularly in the short term.¹³⁸ But Indian farmers could profit from adopting low-marginal-cost, cloud-based digital solutions that would scale easily to support many small farmers. Available, low-cost solutions can also help address the water issues that India faces.¹³⁹ Vapour-transfer irrigation systems, for example, could equip farmers to use water efficiently and use brackish or saline water without expensive purification, desalination, fine filtering, or pressurising.¹⁴⁰

Digitally enabled asset- and knowledge-sharing solutions. Digital platforms offer opportunities for sharing machinery so that small farmers can benefit from economies of scale. Leveraging the aggregated knowledge of many farmers, other digital platforms can be used to share knowledge of best practices in regenerative agriculture, as well as location- and crop-specific information.

Asset sharing can increase innovation, productivity, and yield. High fragmentation of land has limited the adoption of innovation in India,¹⁴¹ as farms are often too small to justify the capital investment required to implement more efficient technologies and systems. As a result, average yield rates in the Indian agricultural sector are low by international standards.¹⁴² Sharing platforms can give farmers access to machinery that they otherwise would not be able to afford.

Examples are emerging in India. The start-up EM3 Agri Services and Mahindra Group's Tringo have developed platforms that employ use-and-pay models for farm equipment, and the state of Rajasthan is planning to launch over 2,600 farm equipment hiring centres in the next three years.¹⁴³ These sharing models enable Indian farmers to increase productivity and yield, without buying expensive equipment.

Digitally enabled knowledge-sharing solutions are expected to encourage adoption of best practices, increase yield, and advance regenerative agriculture. These solutions would let farmers share local and traditional knowledge on a peer-to-peer basis and receive information on innovative practices customised to their region and crops.

In India, Digital Green and ITC's e-Choupal platform are already offering such solutions. Digital Green is a non-profit organisation that trains farmers in more than 2,000 villages to make and show short videos (accommodating

local dialects and literacy challenges) that record their problems, share solutions, and highlight success stories.¹⁴⁴ (For more on e-Choupal, see *e-Choupal internet access*.)

Digitised food supply chains. Digital platforms that transmit accurate market information relevant to food producers (especially information on price and size and location of demand) and connect those producers more closely with their customers improve inventory and production management and cut supply chain costs.

Indian farmers sell their produce much as they have for the last 50 years. The system relies on the government-regulated Mandi marketing channel that, according to the Task Force on Agricultural Development constituted by NITI Aayog, is "characterised by inefficient physical operations, excessive crowding of intermediaries, long and fragmented market chains, and low scale ... depriving farmers of fair share of the price paid by the final consumer."¹⁴⁵

Digital supply chain solutions increase transparency, decrease the high transaction costs attributable to multiple and various intermediaries, and better connect producers with customers. These solutions also enable better inventory management and self-organised production optimisation across small-hold farmers. Knowing the size and timing of demand, farmers can use digital technology to coordinate, adapt, and optimise the supply of food to their region, reducing price volatility and increasing their income.¹⁴⁶ The Indian government recently launched a pilot initiative connecting 21 regional markets with digital technology. This should overcome some of the problems with the Mandi system.¹⁴⁷

Several other initiatives are also tackling these issues along the food supply chain in India. As part of its Social Investments Programme, ITC launched e-Choupal to address market inefficiencies along its own supply chain (see *e-Choupal internet access*). The RUDI Sandesha Vyavhar, a collaboration between Vodafone and the Self Employed Women's Association, uses simple mobile phone technology to create an automated supply chain management platform for women in Gujarat, helping them sell farm produce in their local communities. The initiative claims to have expanded business opportunities and quadrupled the income of more than 50% of the participants.¹⁴⁸

Other solutions are tackling the issue at the retail level. Automated replenishment solutions for fresh food are emerging, reducing food waste at retailers.¹⁴⁹

E-CHOUPAL INTERNET ACCESS

Launched by the Indian conglomerate ITC, e-Choupal seeks to increase the economic and competitive capacity of farmers and agricultural communities by providing internet access to rural farmers.¹⁵⁰

The e-Choupal platform gives farmers access to market information and best practices via computers in the homes of farmers trained to use ITC's agricultural website.¹⁵¹ The system provides demand information for available markets, reducing the mismatch of supply and demand that often forces farmers to discard parts of their produce. Pricing information positions farmers to exploit trends and time their sales to get the best price.

The e-Choupal platform builds farmers' understanding of the market, reducing the need for the intermediaries who traditionally control the trading process.¹⁵² e-Choupal also enables farmers to share advice on managing risks like soil contamination or salinity.

Farmers have definitely benefitted from e-Choupal. Data on acreage and yield, 2000-2012, shows that profits of farmers accessing the e-Choupal platform almost tripled. Soya farmers learned how to apply scientific farming practices to reduce seed use from 40-45 kg per acre to 30-35.¹⁵³ In 2015 four million farmers used the service via 6,500 e-Choupal access points spread over 40,000 villages in 11 states.¹⁵⁴

Peri-urban and urban farming. Bringing food production and consumption closer together by increasing agricultural activity in and around cities reduces food transport and associated costs (such as food waste, fuel, and environmental externalities) and tightens biological nutrient cycles, while increasing access to fresh, healthy food and creating new income streams. Specialised urban farming techniques (like vertical, hydroponic, and aquaponic farms) can be more resource-productive than traditional cultivation techniques, saving on energy, water, and fertiliser.

Rapid urbanisation in India moves food demand closer to urban centres that are also experiencing problems with overheating.¹⁵⁵ Peri-urban and urban farming could help overcome some of these challenges, while providing a new source of employment and income.

Several studies have highlighted the potential of peri-urban and urban farming. One Michigan State University analysis computed a scenario, according to which moving towards locally supplied fruits and vegetables in Michigan would create almost 1,800 jobs and US\$ 211.5 million in new income.¹⁵⁶ Another study by the University of California showed that farmers' markets in food-insecure areas offered more affordable and higher-quality produce than neighbourhood corner stores and supermarkets and, in some cases, provided enough competition to force lower supermarket produce prices.¹⁵⁷

Urban and peri-urban farming can take many forms. It can thrive in highly controlled environments, including vertical farms (in or

on top of buildings), hydroponic agriculture (growing plants with their roots in a solution of water and nutrients instead of soil), and aquaponic farms (combining aquaculture and growing of vegetables).¹⁵⁸ In less controlled settings, organisations like the Institute of Natural Organic Agriculture (INORA) are helping households convert their unused spaces like rooftops, terraces, or balconies into spaces for urban farming that can enable local nutrient recovery (see *Institute of Natural Organic Agriculture*).^{159,160}

While not all crops can grow in an urban environment, and scaling presents challenges, urban farming works well for highly perishable vegetables and herbs, delivering them to consumers fresh with little investment in resources and transportation. High-tech, industrialised urban farming, supported by collaboration among agri-businesses and researchers,¹⁶¹ is also gaining traction. For example, the Agro Food Park in Denmark hosts 75 companies on 44,000 square metres of urban land and is expected to grow dramatically.¹⁶²

Returning nutrients to the agricultural system.

Not all biological nutrients that reach their place of consumption are actually used. Some end up as household or industrial food waste; others are consumed but not absorbed by the human body and discharged in human excreta. Processes like composting and anaerobic digestion can recover these nutrients for return to the agricultural system and, in the case of anaerobic digestion, produce energy.

INSTITUTE OF NATURAL ORGANIC AGRICULTURE (INORA)

An NGO based in Pune, INORA works in research, education, and technology transfer for regenerative farming and nutrient recovery, specifically composting and anaerobic digestion. INORA's decentralised technological solutions enable the transformation of food waste into nutrients that the agricultural system can use in both rural and urban settings.

INORA serves single households, housing complexes, industrial kitchens, farms, and municipalities. The company processes material for over 300 housing societies, 35 schools, and 14 industrial projects and works with some 100,000 citizens and 300 organic farmers.¹⁶³

INORA's anaerobic digestion technology can be small enough for use in a single building, with units built to digest about 3 kg of food waste a day that produce 90 minutes' worth of gas for cooking, as well as 60 litres of liquid organic fertiliser. This fertiliser contains enough nutrients for an urban farming project, such as a small roof-top garden with about 250 plants. INORA's larger anaerobic digestion plants can process approximately 5 tonnes of food waste a day and produce biogas equivalent to 300 kWh of energy, as well as some 10 tonnes of biogas slurry.

INORA has also implemented industrial composting solutions that can process 2 tonnes of food waste a day and produce 400 kg of compost.



Image credit: Inora

While avoiding food waste should be a priority along the supply chain, and several opportunities mentioned above can contribute to this reduction, residual food waste in industrial and household kitchens is unavoidable. Biorefineries can process this waste to produce high-value chemicals and nutrients, and capture the remaining value in the form of fertiliser (digestate) and energy (biogas) using anaerobic digestion.

Indian non-profits and businesses, in cooperation with municipalities and the informal sector, are already implementing composting and anaerobic digestion solutions capturing these nutrients. INORA, for example, offers anaerobic digestion technologies and advice to commercial and residential users (see *Institute of Natural Organic Agriculture*). Mailhem offers

customised solutions for solid bio-waste and wastewater treatment and management. These solutions use biomethanation techniques to treat solid and liquid waste, generating biogas and organic manure.¹⁶⁴

India still lacks adequate sanitation infrastructure, and decentralised human excreta recovery technology has yet to reach scale in India or around the world. This represents a significant opportunity for government and businesses in India to avoid linear lock-ins and develop circular sanitation infrastructure to recover and valorise biological nutrients.

In dense urban areas, capturing this opportunity might require a centralised, coordinated approach to public sanitation infrastructure (see *Biopolus: The future of urban water systems?*, p.

32). In sparser rural or rapidly developing urban regions, decentralised solutions that enable on-site processing show significant potential to valorise these nutrients. Blue Diversion's Autarky toilet project, developed by the Swiss Federal Institute of Aquatic Science and Technology, has built one such technology. This self-sustaining, off-grid reactor treats urine, faeces, and water separately.

Collaborative initiatives can enable implementation of such solutions. The Toilet Board Coalition, for example, is a business platform that connects experts and businesses, large and small, with the aim of achieving universal sanitation by 2030. The coalition has adopted an approach based on circular economy principles and is building evidence that 'toilet resources' (the coalition's term for human excreta) have value in multiple uses. The coalition seeks private-sector participation in scaling solutions for locations that do not have a central sewage system.

POTENTIAL DEVELOPMENT PATHS

The outcome of decisions made about pursuing these opportunities will lead India down different development paths with widely varying environmental, economic, and social outcomes. The following outlines two of the many potential scenarios. These are not intended as projections, but as estimates of the order-of-magnitude impact of the development paths. For a detailed comparison of the scenarios, see Appendix A.

Current development scenario. This path would likely bring India a more resource-efficient food system, with higher short- and medium-term yields but little system-level resilience and doubtful long-term food security. The efficiencies created by adopting precision farming and improving bioscience, storage, and transportation technologies would increase yield and distribution efficiency.

India would probably see mass intensification and specialisation, subsequent reduction in market and ecological diversity, and therefore low system resilience. The current path would capture the opportunities of nutrient recovery and urban farming only to a limited extent.

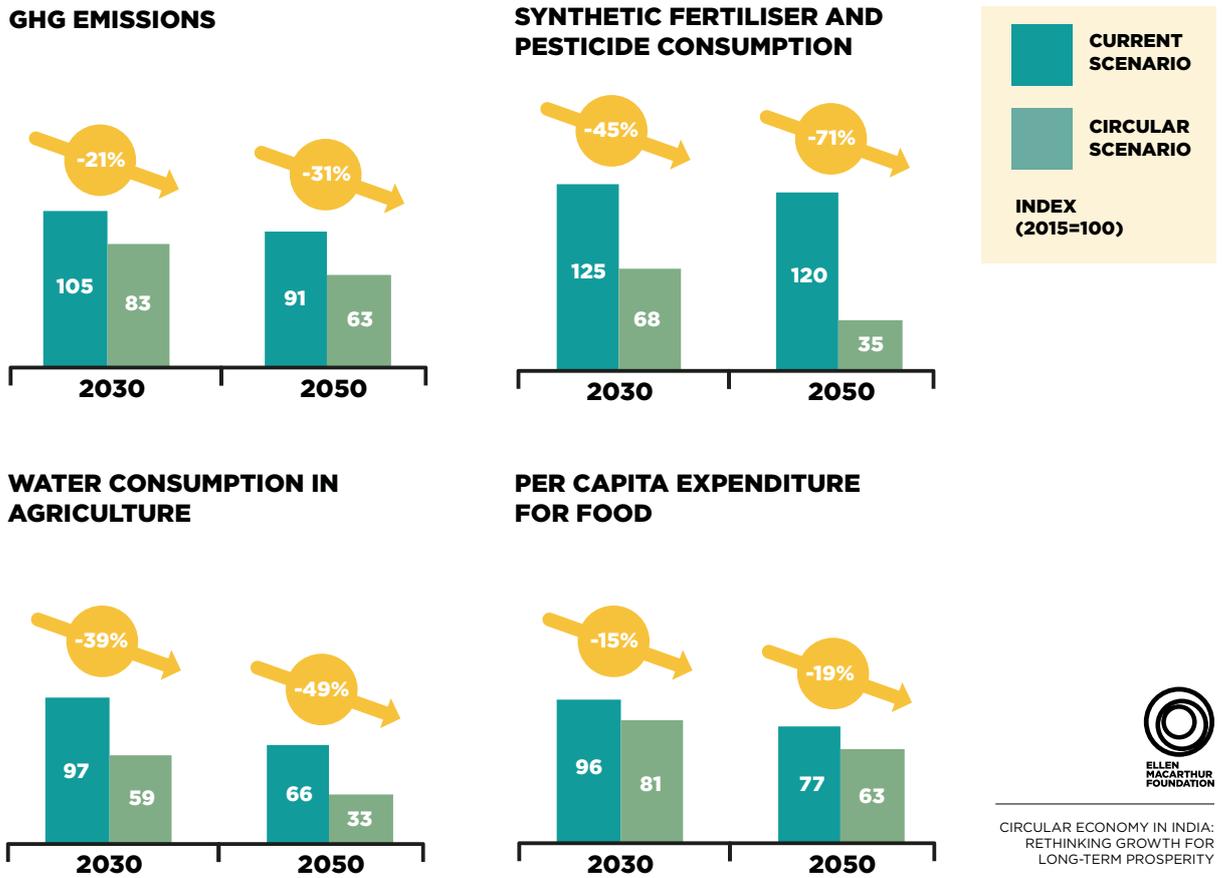
Circular development scenario. Application of circular economy principles would make agricultural production more regenerative, creating a more diverse and resilient food system that could supply fresh, healthy produce to India's growing population. This development path would preserve the integrity of the natural system, phase out toxic materials, and minimise nutrient leakages, reducing negative environmental and health externalities, while supporting rural livelihoods and incomes.

National, state, and municipal governments and businesses would recognise the potential of a circular food system and invest to overcome barriers to its development so the system would enjoy greater output and long-term resilience. A circular development path would largely capture the opportunities of digitalisation, recovery of nutrients, and urban farming, decreasing the cost of food production and increasing food security.

Quantified benefits

Overall, following a circular economy development path could generate annual benefits of ₹3.9 lakh crore (US\$ 61 billion) in 2050, compared with the current development path. Following the circular path would also reduce negative environmental impact, with 31% less GHG emissions from agriculture, 71% less use of synthetic fertilisers and pesticides, and water consumption for irrigation almost halved. Per capita spend on food would be 19% lower following a circular development path (see Figure 7).

FIGURE 7: COMPARISON OF POTENTIAL DEVELOPMENT PATHS (FOOD AND AGRICULTURE)



Mobility and vehicle manufacturing



MOBILITY AND VEHICLE MANUFACTURING

Mobility is vital to economic growth as it gives people access to employment, goods, and services and affects business productivity.^{165,166} As India is building new infrastructure to meet its growing mobility needs, today's choices will determine the mid-to-long-term development of the mobility system. A circular economy development path for mobility and vehicle manufacturing could create annual benefits of ₹31 lakh crore (US\$ 482 billion) in 2050, compared with the current development scenario. Applying circular economy principles could also create a highly innovative and effective mobility system, with reduced negative externalities.

As the Indian economy booms, the need for mobility is growing substantially. India saw its annual per capita kilometres travelled by rail almost double between 2002 and 2013,¹⁶⁷ and the car ownership rate almost tripled during the same period.¹⁶⁸

With an increasing population and fast-growing economy, the demand for personal mobility is expected to double or even triple by 2030.^{169,170} The demand is especially high in cities, as urbanisation is proceeding rapidly. The growing demand presents significant opportunities for the Indian vehicle manufacturing industry, which produced 24 million vehicles in 2015, up from 18 million in 2010.¹⁷¹

Car ownership in India is low. The car ownership rate per capita in India averaged 1.6% in 2011.¹⁷² Even in urban areas, only small portions of the population own a car. In Delhi, for example, the car ownership rate is 14%,¹⁷³ and most urban trips rely on public transport, services like taxis and auto rickshaws, or non-motorised modes of transportation; 63% of motorised trips used public transport, 9% auto rickshaws, and only 28% private vehicles.¹⁷⁴

Indian cities already face challenges with high congestion, pollution, and accident rates that will grow more severe as mobility demand increases. The large, dense population and rapidly growing mobility demand are exacerbating congestion, pollution, and safety issues. The WHO lists ten Indian cities among the 20 most polluted in the world.¹⁷⁵ The road fatality rate has risen steadily, up 50% between 2000 and 2015.¹⁷⁶ Mumbai and Kolkata ranked among the world's five most congested cities in 2016.¹⁷⁷

India could tap into emerging technologies and business models to create a mobility system that meets the demand of its growing population and minimises negative

externalities. New vehicle and transport technologies are developing rapidly. Digital technology can create new, and improve existing, vehicle-as-a-service solutions to offer attractive alternatives to car ownership and a smart mobility system for cities. Applying circular economy principles would allow India to provide the needed mobility, while minimising negative environmental and health impact.

SIX OPPORTUNITIES TO SHAPE THE INDIAN MOBILITY SYSTEM AND VEHICLE MANUFACTURING INDUSTRY

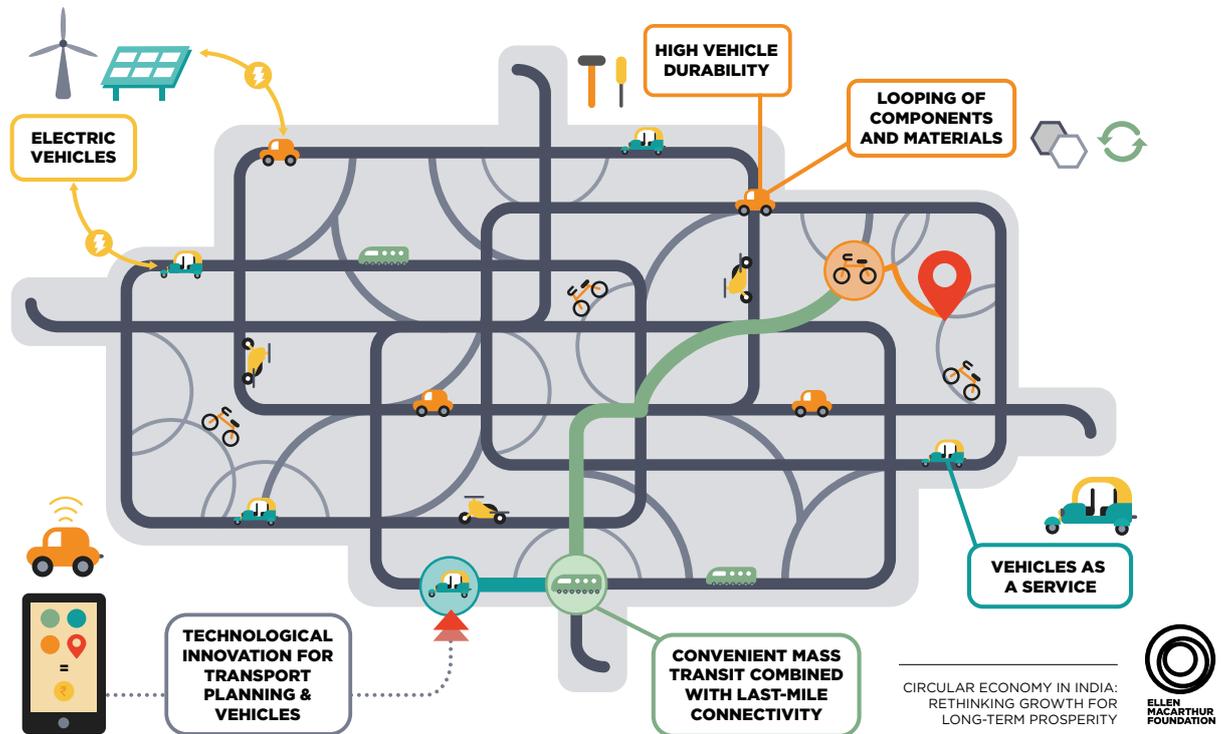
A broad range of circular economy opportunities exists for India to consider when shaping the development of its mobility system and the manufacturing of vehicles. This research identified six major opportunities. To realise the full value identified in the analysis, these opportunities need to be implemented in concert and as part of a strategy that takes into account the whole system (see Figure 8).

Opportunities in mobility

A mobility system based on circular economy principles could combine diverse modes of transport and leverage new technologies and asset-sharing techniques. Digital solutions could allow this multimodal system to work seamlessly, operate door-to-door, and reduce congestion and other negative externalities.

Convenient mass transit combined with diverse and adaptive last-mile connectivity.

A mass transit system with sufficient capacity, speed and comfort can provide the backbone for mobility in Indian cities. Integrated with this system, other forms of transport provide convenient last-mile connectivity or satisfy mobility needs outside of rush hours. Urban planning can adapt density and commuting patterns to reduce transport needs.

FIGURE 8: CIRCULAR ECONOMY IN INDIA FOR MOBILITY AND VEHICLE MANUFACTURING

The already serious congestion and overcrowded public transport¹⁷⁸ in Indian cities, and the increasing demand for urban mobility, call for innovative mass transit solutions. India's Smart City Mission, launched in 2015, encourages the integration of urban planning with diverse transport systems. The mission's guidelines urge cities to promote "a variety of transport options - Transit Oriented Development (TOD), public transport and last mile para-transport connectivity."¹⁷⁹

As part of its smart city proposal, Jaipur plans to develop "smart multimodal mobility." Plans call for integrating various modes of transport, implementing an integrated fleet management system, creating a common ticketing solution via a smart card, providing real-time information and journey planning through mobile apps, and engaging private operators.¹⁸⁰

Given the low car ownership in India, adoption of innovative transportation infrastructure could make car ownership irrelevant in cities from the start. As an example of a city with these ambitions, Helsinki is developing an advanced integrated transport system that will integrate all modes of public,

semi-private, and private transport in a single system that could make private cars irrelevant in the city (see *Helsinki's mobility plan*).

Cities around the world have developed solutions that India could customise to the size, layout, and climate of different cities. Hong Kong, for example, has an advanced integrated public transport system and ranks regularly as a best-in-class city for mobility.¹⁸¹ The city provides commuters with diverse transportation modes. A railway system forms the backbone, connected to 'feeders,' including trams, buses, mini-buses, taxis, and ferries. Users pay for all modes of public transport with one contactless card, the octopus card. Thanks to an innovative business model that enables the operator to profit from real estate price increases in areas surrounding the railway, the Hong Kong transport system is profitable and does not require direct taxpayer subsidies.¹⁸²

Other regions and cities are starting to experiment with innovative transportation solutions. Examples include Hyperloop in California and skyTran in Bihar city.¹⁸³

HELSINKI'S MOBILITY PLAN

Helsinki, the capital of Finland, is planning to transform its transport system by implementing a point-to-point, mobility-on-demand network by 2025.¹⁸⁴ The network will integrate all transport options, including buses, taxis, car pools, and shared bikes, on a single payment platform.¹⁸⁵

The user will access the platform via a smartphone app. The app will function as a journey planner, with the user entering origin and destination and receiving available travel routes. The digital system will enable purchasing mobility in real time with a single click or touch.¹⁸⁶

The transport system will be flexible and effective. The user will buy kilometre-based packages based on time of day, weather, and other variables. Bus routes will be dynamic, changing based on demand.¹⁸⁷ Users will input preferences in the app if they have special needs. Ultimately, the transport system is expected to be convenient enough to compete with private car ownership.¹⁸⁸

Vehicles as a service. Convenient pay-per-use models that give people access to tailored transportation, whenever required, can replace the need for vehicle ownership. Sharing services offer convenient access to diverse vehicles and the latest technologies, increasing vehicle utilisation, and digital technology can enable the sharing of rides to similar destinations, increasing rates of vehicle occupancy.

In India, auto rickshaws are a well-established form of vehicle as a service, handling 10-20% of motorised trips in major cities.¹⁸⁹ New technologies can diversify and improve this concept to maintain attractiveness to users. Ola, for example, provides a mobile app to book taxis and auto rickshaws. The company is extending the concept to ride-sharing, with Ola Share allowing passengers to share a ride and its cost with passengers heading in the same direction.¹⁹⁰

China has applied the concept of on-demand mobility to buses, with Didi Bus providing on-demand service.¹⁹¹ Offering vehicles as a service is especially effective when combined with a reliable mass rapid transport system, complementing it with last-mile connectivity or services outside of rush hours.

As previously noted, car ownership in India today is low compared with Europe or North America, yet owning a car is considered a status symbol.¹⁹² Providing access to a variety of different vehicles through sharing schemes, combined with an effective public transport system, offers a transport solution that can be more attractive than car ownership (which comes with burdens including initial capital

outlay, unexpected maintenance costs, and time wasted searching for parking) and help create new mobility habits.

In sharing schemes for bikes, scooters, and cars, users rent a vehicle for a short period of time. Car-sharing is increasingly popular in densely populated European cities,¹⁹³ especially among younger people who enjoy access to cars without the hassle of ownership.

Car rental companies and manufacturers are already recognising this business potential. BMW and Sixt, for example, created a joint venture called DriveNow in 2011, and Car2go was established as a subsidiary of Daimler AG in 2008. Both car-sharing schemes are popular in Europe. Cars can be parked anywhere in the city and found and booked via smartphone. An electronic card opens and starts the car.

Car-sharing schemes are also starting to get traction in India, with companies like Zoomcar and Myles offering self-drive car rental services by the hour. Membership jumped from 27,000 in 2014 to 175,000 in 2015.¹⁹⁴

Technological innovation for transport planning and vehicles. Digital innovation can help make effective use of diverse transportation modes by creating fast, comfortable journeys. Technological innovation, including in-vehicle connectivity, adaptive cruise control, active safety features, and autonomous driving can reduce congestion and accident rates.

As India's population grows more affluent, the demand for fast, comfortable journeys is increasing. Combined with the right transport options and the availability of vehicles as a

service, trip-planning applications would give people mobility, without car ownership, but with similar comfort, quality, and speed.

Ownership rate of smartphones in India is rapidly growing and expected to reach 58% by the end of 2021.¹⁹⁵ This growth can be leveraged with apps that offer route and transport options based on user preferences for price and comfort, taking into account traffic and weather conditions. Smartphones have already made using public transport easier, particularly in unfamiliar cities, and advanced applications already exist to some extent. For example, GoLA in Los Angeles enables travel planning by showing the transport modes available in the city (metro, bus, tram, Lyft, bicycle, etc.) and offers booking services.¹⁹⁶

Indian commuters suffer severe delays caused by traffic congestion.¹⁹⁷ However, new technology can help make city traffic flow more effectively. Several studies and projects are already mining GPS data to address congestion issues.¹⁹⁸ Such efforts analyse GPS data from vehicles, smartphones, and tablets to pinpoint frequently congested areas and identify potential countermeasures or redirect traffic to other areas.

Some recent studies have investigated how new technologies can be harnessed to develop traffic management systems that are self-regulating and avoid the pitfalls of a centralised top-down approach.¹⁹⁹ Traffic lights, for example, can be self-organised based on measurement of traffic flows in intersections and on traffic light information. Simulated on a highly congested area in Dresden, Germany, such an approach reduced bus and tram delays by 50%, compared with top-down traffic management.²⁰⁰ Combined with autonomous driving and in-vehicle connectivity, self-regulating traffic could ultimately make traffic lights irrelevant and reduce queues and delays.²⁰¹

Autonomous driving is becoming a reality with the launch of self-driving taxis tested in Singapore in 2016.²⁰² Advances in autonomous driving have outpaced regulation to date, but the technology offers opportunities to optimise traffic, reducing congestion and fuel consumption.

Technological advances, including autonomous driving, can also contribute to the reduction of the high number of accidents in India, which is a growing concern: 146,133 people were fatally injured in road accidents in 2015, according to official government data – 4.6% more than in 2014.²⁰³

Opportunities in vehicle manufacturing

Vehicle manufacturing based on circular economy principles would extend vehicle usage, loop materials, and reduce externalities.

Electric vehicles. Electric vehicles (EVs, e.g. powered by batteries or fuel cells) reduce pollution and, combined with decarbonised energy, GHG emissions. Taking a systemic approach to fitting EVs into the city electricity grid can make EVs part of the energy system and support renewable energy production.

India faces rampant air pollution issues, due partly to increasing numbers of vehicles. Shifting to EVs presents an opportunity to avoid getting locked into usage of a high number of fossil-fuel-burning vehicles. The Indian government identified EVs as a viable solution to pollution and oil dependence issues and, in 2013, launched the National Electric Mobility Mission Plan (NEMMP) 2020. The plan seeks to increase the share of EV sales via fiscal and monetary incentives. The target is sales of 6-7 million electric or hybrid vehicles by 2020.²⁰⁴

Advances in battery-powered vehicles in recent years have made them more attractive in terms of performance and economy. Companies like Tesla are significantly improving EV performance by investing in research²⁰⁵ and making its patents available to encourage innovation.²⁰⁶ Having fewer moving parts and no oil or filter to change, EVs have lower maintenance costs²⁰⁷ and – with energy costs already lower than conventional cars and technological improvement of batteries reducing initial purchase prices²⁰⁸ – EVs are expected to become a more economical option for the Indian market.²⁰⁹ Car-sharing schemes often use small electric cars because they can recharge while parked and have lower maintenance costs.²¹⁰ Supported by the NEMMP, Indian companies are starting to embrace electrification and developing customised solutions for the market. In 2013 Mahindra launched the Mahindra e2o, an urban electric car that the car-sharing scheme Zoomcar uses (see *Mahindra e2o and Zoomcar*).²¹¹

India could also integrate EVs into the energy system. Vehicle batteries can support renewable energy production by being programmed to charge during peaks of production.²¹² SonoMotors, an innovative German-based maker of EVs, is developing the viSono system that integrates solar cells into the body of the vehicle and produces enough energy to drive 30 kilometres a day.²¹³

Electrification is also becoming increasingly attractive for two wheelers, which remain the largest segment of the Indian vehicle market, with over 16 million units sold in 2015-16. In 2015 the start-up Asther Energy raised ₹77 crore (US\$ 12 million) to develop the Ather S430 for the Indian market.^{214,215}

For vehicles that travel long distances, like buses and commercial vehicles, fuel cells offer a viable power option because of their distance capacity and rapid refuelling. Tata, for example, sells a fuel cell version of its Tata Starbus²¹⁶ and this year launched the Tata Magic Iris Ziva,²¹⁷ a small passenger carrier.

MAHINDRA E2O AND ZOOMCAR

Mahindra launched the e2o, an EV designed for urban use in 2013. The car is available for purchase or use through car-sharing pools.²¹⁸

The EV has a charging chord that plugs into a regular 15 amp socket and needs 90 minutes to power a cruising range of 100-130 kilometres.²¹⁹ The car is complemented by an app for monitoring performance metrics, charging status, remaining range, and other features.²²⁰

Innovative solutions enable more efficient utilisation of the car and its components. Mahindra's collaboration with the car pool Zoomcar allows users to pay per hour, day, or week, rather than having to own the car.²²¹

In Bhutan, customers can also opt for the 'Goodbye Fuel Hello Electric' programme. When they buy the EV, Mahindra retains ownership of the car battery, guaranteeing its performance for a monthly usage fee.²²²

High vehicle durability. Designing vehicles to be easily maintained and repaired helps retain their value by keeping them in use longer. Effective collaboration with existing actors undertaking maintenance and repair, such as the informal sector, can capture value. Counteracting an expected increase in the complexity of vehicles, novel technologies like 3D printing of spare parts can keep decentralised vehicle repair feasible.

India has a high rate of vehicle repair, especially for two and three wheelers, with repairs mainly performed by the informal sector.²²³ But, as customers shift to cars and the complexity of vehicles increases, these high rates are likely to drop.

Keeping vehicles easy to maintain and repair would maximise returns for businesses offering leases or vehicles as a service by prolonging the use of their assets. The small UK-based company Riversimple has taken this approach with its new Rasa. The company employs a new business model for car manufacturing that maximises profit by improving vehicle durability, reparability, and remanufacturing (see *Riversimple vehicles as a service*).

Looping of components and materials.

Designing vehicles for reuse, components for remanufacture, and materials for recycling can close loops and reduce upstream demand for materials and energy. Coupling this with circular business models, such as product as a service, maximises value capture for businesses. Collaboration with the informal sector can create the necessary reverse logistics networks.

Remanufactured parts can be 30-50% less expensive while having the same guarantee and quality control as new parts.²²⁸ Remanufacturing a passenger car engine uses only 23% of the energy used to produce a new engine from raw materials.²²⁹ Businesses that identify ways to close material loops can realise greater profit margins through alternative revenue streams and lower manufacturing costs.

Indian companies are starting to recognise these benefits. Taking them to scale across the automotive industry would offer a significant opportunity to create resource-effective mobility solutions.

RIVERSIMPLE VEHICLES AS A SERVICE

UK-based car manufacturer Riversimple provides vehicles as a service. Instead of buying cars, customers pay a monthly fee that covers use, maintenance, insurance, and fuel, while Riversimple retains ownership.²²⁴ Riversimple thus takes a whole system approach to its value chain and strives to maximise use of materials and components.

Riversimple leases most car components from suppliers, assembles the car, and leases it to customers. The business model makes efficiency profitable and gives both Riversimple and its suppliers an economic incentive to design the car and components to last. The longer the car and its components last, the longer Riversimple and the suppliers generate revenue from them.²²⁵

Riversimple cars operate efficiently. Rasa, Riversimple's first and only model, uses a hydrogen-powered fuel cell that does not emit any GHG, only water. The car is made of strong, light composite materials that reduce its kerb weight to 580 kg, allowing a range of around 500 kilometres.²²⁶ The Rasa is set to be commercially available by 2019,²²⁷ and Riversimple is planning to make the technology open source to enable fast adoption in different markets.



Image credit: Riversimple

Tata Motors Prolife, for example, has realised the value of remanufacturing components in their commercial vehicles as these vehicles have long use cycles, are very sensitive to cost increases, and are often managed as a fleet, making the use of remanufactured parts more attractive, especially with a warranty. Tata Motors Prolife will buy back, or exchange, used vehicle parts like the engine, gearbox, or alternators. Tata Motors Prolife then remanufactures the returned part and offers the remanufactured product with a warranty. This approach allows longer use of parts, reduces demand for energy and materials, and creates new revenue streams for Tata Motors Prolife.^{230,231}

GIZ expects the number of vehicles coming out of service each year in India to increase from 8.7 million in 2015 to 21.8 million units in 2025 – an increase of 250% in 10 years.²³² Today the informal sector handles most of the dismantling of those vehicles, recovering high-value materials like steel and discarding low-

value materials, often in ways that create health risks for the dismantlers and people living in surrounding areas.²³³

As the vehicle market grows, India has significant opportunity to create a system – from vehicle design to reverse logistics – that incorporates informal sector activity, enables capturing material value after use, and prevents health risks for dismantlers and people living nearby. This system would also give manufacturers a reliable and economical supply of raw materials.

Governments could provide supporting legislation to increase recycling rates. Indeed, the Indian government is currently working on a regulation, AIS 129, to define the legal framework for effective looping of materials in the automotive sector.

Similar initiatives in other countries have had some success. The European End-of-Life Vehicle Directive integrates the concept of

extended product responsibility. The directive sets clear targets for toxicity of materials and recycling/recovery rates. To achieve the targets, manufacturers and recycling centres have collaborated to increase recycling. Countries like Austria achieved 86% reuse and recycling in 2014, compared with 80% in 2006.²³⁴

POTENTIAL DEVELOPMENT PATHS

The outcome of decisions made about pursuing these opportunities will lead India down different development paths with widely varying environmental, economic, and social outcomes. The following outlines two of the many potential scenarios. These are not intended as projections, but as estimates of the order-of-magnitude impact of the development paths. For a detailed comparison of the scenarios, see Appendix A.

Current development scenario. Cities would follow a development path centred around private vehicles. Public transport and vehicles as a service would increase, along with the demand for mobility. But a non-systemic approach to transport planning would preserve private vehicles as a convenient option, and traffic congestion would remain high.

Use of electric vehicles and renewable energy would increase, thanks to government incentives, but would still considerably lag behind internal combustion engine vehicles. Vehicle usage length would shrink, as vehicle design becomes more complex, technical

innovation increases, and new vehicle sales prove very profitable. Regulations would increase vehicle recycling rates.

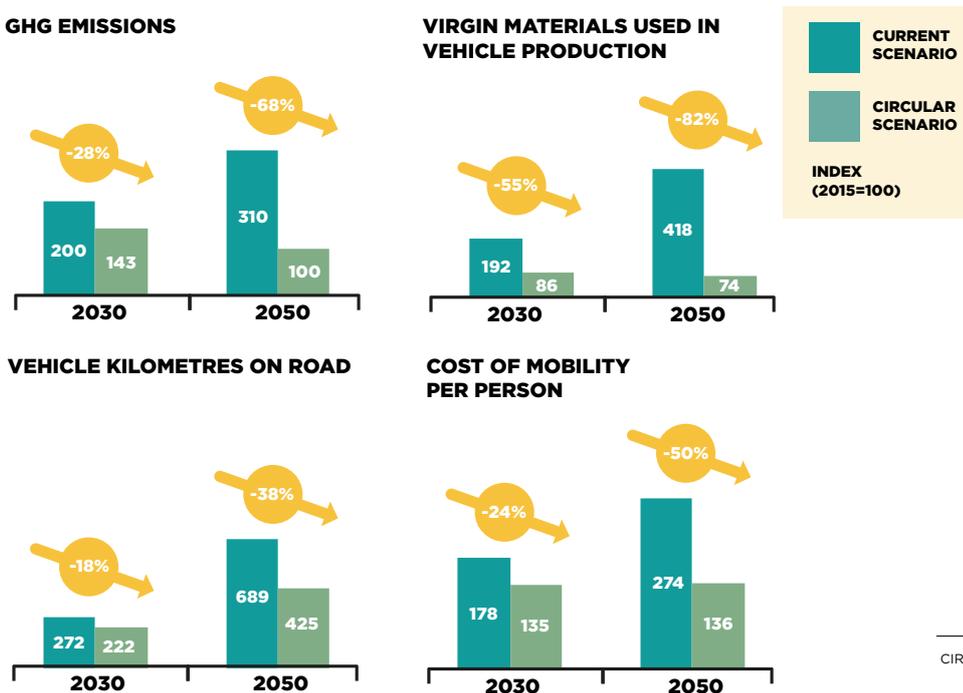
Circular development scenario. Transport planning would diversify transportation modes and develop a multimodal system optimised by new technologies. Private vehicle use in urban areas would decline as the transport system would offer convenient and inexpensive ways to navigate the city. Electric vehicles would predominate, reducing noise and pollution and improving quality of life.

Vehicle manufacturers would develop new business models and revenue streams to profit from designing long-lasting, upgradable, and efficient vehicles. Manufacturers would collaborate with those currently handling repair and recycling and would design vehicles for longer use and easier remanufacturing and recycling.

Quantified benefits

Following a circular economy development path could generate annual benefits of ₹31 lakh crore (US\$ 482 billion) in 2050, compared with the current development path. Following the circular path would also reduce negative environmental impact, with 68% less GHG emissions from transportation and vehicle manufacturing and 82% less consumption of virgin materials. Per capita spend on mobility would decrease 50% (see Figure 9).

FIGURE 9: COMPARISON OF DEVELOPMENT PATHS (MOBILITY AND VEHICLE MANUFACTURING)



BENEFITS OF A CIRCULAR ECONOMY FOR INDIA

BENEFITS FOR BUSINESSES AND THE ECONOMY

Profit opportunities for businesses through increasing innovation and demand for new business services. By applying circular economy principles, businesses could generate new ideas and explore new ways of working, especially in digital technology. Indian innovation hubs could help businesses implement new approaches and capture new profit opportunities.

A circular economy would create new demand for business services, such as reverse logistics, remarketing, remanufacturing, and refurbishment.²³⁵ Circular economy practices could offer new ways to engage customers by offering service model contracts that build long-term customer relationships. Concrete profit opportunities, for example, through the processing of food waste and better vehicle repair and remanufacture, have been identified in this research. While the research did not quantify these opportunities individually, previous analysis by the Ellen MacArthur Foundation has shown clear profit opportunities in these and other applications of circular economy principles.²³⁶ Circular economy ideas could also be included in government programmes like Digital India and Make in India, supporting businesses in capturing the opportunities.

Material cost savings and reduced exposure to resource price volatility. A circular economy would significantly lower costs for businesses related to the use of virgin materials. Less material use would also reduce their exposure to volatile raw materials prices and strengthen resilience.

The analysis showed, for example, that circular economy approaches could save ₹1.0 lakh crore (US\$ 16 billion) in 2030, increasing to ₹2.0 lakh crore (US\$ 31 billion), on annual material costs for constructing residential and commercial buildings. Similarly, in the circular economy scenario, consumption and therefore total costs of synthetic fertiliser would be 39% lower in 2030 and 62% lower in 2050 compared with the current development path.

These results are consistent with analyses in other economies. Detailed product-level modelling of complex, medium-lived products in the EU found annual net material cost savings of up to US\$ 630 billion in an advanced circular

economy scenario.²³⁷ Analysis of fast-moving consumer goods showed additional, global savings potential of up to US\$ 700 billion.²³⁸ Countries like India that have a growing middle class and expect more material-intensive consumption stand to capture a significant share of this value.²³⁹

Economic growth. As mentioned above, circular economy practices are making more productive use of material inputs (including looping of products, components, and materials) and increasing revenue from emerging circular activities. While some sectors (e.g. the material extraction industry) would expect reduced activities, overall more activity would happen across the economy, boosting economic growth.

Quantifying these impacts for India would require detailed modelling of the effects on GDP of the lower cash-out costs and other benefits identified in this report. This analysis would also have to quantify opportunity costs and costs of externalities and take into account consumption increases triggered by higher household income.

Economic modelling for Europe has shown that reducing annual cash-out costs €0.6 trillion (4.5% of the EU's GDP) would increase GDP 7% by 2030.²⁴⁰ India might expect similar impact from the reduced annual cash-out costs of ₹14 lakh crore (US\$ 218 billion, 11% of India's GDP).

BENEFITS FOR THE ENVIRONMENT

Lower GHG emissions. In all three focus areas studied, GHG emissions would be substantially lower in the circular scenario than in the current scenario. In the built environment, using fewer virgin materials, applying more efficient construction techniques, and reducing electricity use in cooling would reduce GHG emissions 23% in 2030 and 40% in 2050. In the agricultural system, GHG emissions from land and energy use and production of artificial fertiliser would be 21% lower in 2030 and 31% lower in 2050. Overall, Indian GHG emissions would be 436 million tonnes of CO₂ equivalent (Mt CO₂e) lower in 2030 and 1,042 Mt CO₂e lower in 2050.

Reduced consumption of virgin, non-renewable materials and energy. The extraction of virgin materials and the production of energy from non-renewable sources like coal and oil have significant negative environmental externalities, like GHG emissions, toxic materials, and other pollutants leaking into local environments.

Following a circular economy development path would lead to reduced consumption of virgin, non-renewable materials of 25% in 2030 and 38% in 2050 compared with the current scenario. This reduction would be primarily thanks to a construction industry that would rely more on renewable material and the recycling of construction and demolition waste, rather than bricks, steel, and concrete made from virgin, non-renewable input. Applying circular economy principles in the mobility sector would similarly cut energy consumption in transport – 33% in 2030 and 66% in 2050 – and reduce the use of virgin materials in vehicle production. Energy consumption would be 24% lower in 2030 and 41% lower in 2050 in the circular economy development path compared with the current path.

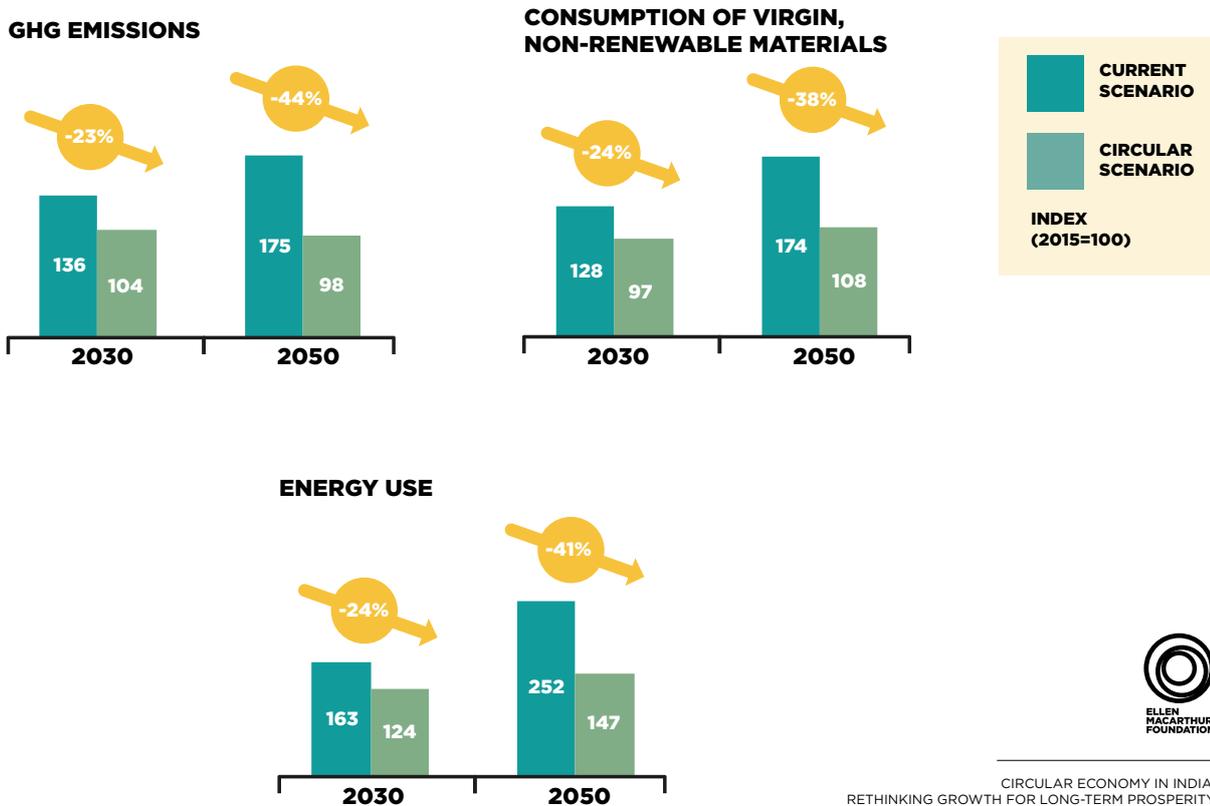
Increased land productivity and soil health.

India is facing significant issues related to soil degradation (see p. 17). Applying circular economy principles to the food and agriculture

sector would increase land productivity, decrease waste in the food value chain, and return nutrients to the soil. These efforts would enhance the value of land and soil assets by increasing their regenerative potential. The analysis showed that implementing circular economy approaches, especially regenerative agriculture at scale would lower consumption of synthetic fertilisers 49% in 2050, compared with the current scenario.

Reduced water use. Across the three focus areas studied, a circular scenario would reduce water consumption significantly, compared with the current scenario. The agricultural system would use 39% less irrigation water in 2030 and 49% less in 2050. City households would use 14% less water in 2050, decreasing pressure on water supply in India’s growing urban areas. The amount of water needed to produce virgin materials (especially in the construction industry) would also be significantly lower.

FIGURE 10: COMPARISON OF DEVELOPMENT PATHS



BENEFITS FOR CITIZENS

Lower cost for products and services. In the circular economy scenario, cash-out cost in the three focus areas would be ₹14 lakh crore (US\$ 218 billion, 11% of India's GDP) lower in 2030 and ₹40 lakh crore (US\$ 624 billion, 30% of India's GDP) lower in 2050, compared with the current scenario.

These declines would decrease the cost for households to access the products and services needed for housing, food, and mobility and therefore increase disposable household income. For example, per capita cost to meet the same level of mobility demand would be 24% lower in 2030 and 50% lower in 2050. Analysis of the relationship in Europe between cost savings in the same three systems and disposable household income found that €0.6 trillion (4.5% of the EU's GDP) lower cash-out costs would lead to 10% more disposable household income in 2030.²⁴¹

Lower costs in the food system would also help India implement the National Food Security Mission. Lower costs for housing would support the Pradhan Mantri Awas Yojana (Housing for All) initiative.

Greater utility and choice. The additional choice or quality that circular models provide would enhance the utility, or benefit experienced by customers. Choice increases as producers provide systems that enable tailoring products

or services to better meet customer needs. For example, applying circular economy principles in mobility would give customers more vehicle options, without increasing the number of vehicles on the road.

Reduced negative externalities, e.g. congestion, pollution. The analysis suggested beneficial impact from applying circular economy approaches to address issues like congestion, pollution, and ill health.

For example, the circular development path would lead to a reduction in vehicle kilometres travelled on roads by 38% in 2050, compared with the current path, decreasing congestion and time spent in traffic. More zero-emission vehicles and regenerative farming techniques that eliminate the need for crop burning, would reduce inner city pollution and the associated negative effects on health and productivity. Less use of pesticides (-76% in 2050) would improve the health of farmers.

Detailed modelling of the implications of the two development paths on other externalities and the associated (non-cash) costs (including opportunity cost) exceeds the scope of this report, but would be necessary to estimate more exactly the systemic impact of applying circular economy principles in India.

CHAPTER 3 — CAPTURING THE BENEFITS



CHAPTER 3 — CAPTURING THE BENEFITS

Realising the circular economy opportunities described in this report requires action by many stakeholders. Businesses have the opportunity to lead the way in the transition to circular models, and governments can create the right enabling conditions for their adoption. Collaboration between these and other actors, including the informal sector, educational institutions, non-profits, and international organisations will be key to creating systemic change. In the short term, setting up such collaborations, engaging additional stakeholders, and undertaking further research could strengthen the foundations needed to begin the transition.

INDIAN BUSINESSES ARE WELL PLACED TO LEAD THE WAY IN THE TRANSITION

Businesses stand to realise substantial profit from the circular economy opportunities outlined in this report. The following five recommendations could guide companies in capturing this value.

Build circular economy knowledge and capacity. Taking maximum advantage of circular models requires decision-makers throughout the organisation to understand the benefits and take them into account in business decisions. To put circular economy principles into practice, current and prospective employees need training on circular product design, new business models, and reverse logistics.

Lack of awareness and low confidence in the benefits that circular economy models can bring would limit the number of offerings in the market. Businesses need to raise awareness of circular economy principles, and build their capacity, to support the identification of business opportunities and drive the implementation of circular models.

For businesses to shift to circular models requires an appreciation of their impact across all business functions. For example, shifting to a vehicles-as-a-service model could increase profits and decrease exposure to risks such as the price volatility of resources, both matters of interest to the finance and strategy functions. Retaining ownership of the vehicles, in order to repair and refurbish them, remanufacture their components, and recycle their materials, will affect the design function, which will need to redesign products for durability and ease of disassembly. The purchasing function would need to reduce the quantities (and possibly change the type) of raw materials it bought,

the finance function would need to deal with an expanded balance sheet, and the customer service function would need to provide a different type of support to customers. The company would also need to set up a reverse logistics function to retrieve vehicles.

Fostering the right skills will be key to accelerating the rate at which businesses transition to circular economy activities. For example, providing training in new fields like design for disassembly and effective reverse logistics.

Furthermore, greater awareness of, and deeper knowledge about, new technologies and circular economy business models are needed. For example, for the construction sector to shift to modular and adaptable buildings, designers and architects need to be trained on these construction methods so they can select the most economic and locally appropriate design features for India's varied climatic conditions. Maximising the benefits of recent technologies, for example Building Information Modelling, which can support circular design by tracking data on the materials used in construction, will likewise require user training.

Innovate to create new products and business models and demonstrate their success. Being at the forefront of implementing circular economy principles and digital technology can create competitive advantage and critical industry momentum. Businesses can foster innovation to address challenges, such as transition costs, more rapidly by collaborating with research institutions and by making information open source. Both established businesses and start-ups can profit from the innovation opportunities, providing an attractive outlet for entrepreneurship in India. Successful pilot projects can demonstrate the value of circular economy models internally and externally.

In the short-term, investment might be needed to start circular economy activities, and they might achieve overall profitability only in the medium- or long-term. For example, to realise the greatest value from performance-based models, it makes sense for manufacturers to invest in sourcing and producing components that last longer, are easier to repair, are constructed of more sophisticated materials, or by special manufacturing processes. While costs for these alternative production methods and the requisite research and development can increase the upfront investment required, lower maintenance and repair costs as well as higher utilisation rates can result in higher overall profit.

Despite a clear business rationale, the adoption of new models, like vehicles as a service in India, require overcoming socio-economic challenges, such as the status associated with asset ownership. Business could play a key role in shifting perceptions by innovating to create circular solutions that offer at least comparable convenience, luxury, and comfort. For example, a company giving customers access to all kinds of vehicles whenever they want and maintaining those vehicles, offers access to more people at lower cost than ownership, and could therefore prove more attractive than buying a vehicle.

Wider public scepticism about the reliability or safety of new technologies, such as electric and autonomous vehicles, could be a stumbling block. Pilot projects could demonstrate successful and safe products and services and pique market interest. Tesla, for example, managed to change the perception of electric vehicles from a cheap, unreliable choice to a high-quality luxury option. Research institutions could build understanding of the Indian market and consumer preferences and collaborate with businesses and the government to develop standards to boost customer confidence in new technologies.

In other markets, unconventional approaches are accelerating innovation toward new business models. Open-source sharing of knowledge can build critical momentum for a new direction. Tesla Motors, for example, makes all its patents for the technology used in their electric cars available to the public.²⁴² Tesla recognises that patents can limit innovation, and collaboration can produce solutions to difficult technical challenges and achieve adoption more rapidly.

Integrate circular economy principles into strategy and processes. To have the right incentives for value creation in place, circular economy aspects should be taken into account when designing an organisation's governance structure and decision-making processes. In

particular, this would mean including incentives for medium- and long-term value creation opportunities – as well as for cross-functional collaboration – in company strategy.

Developing circular models often involves transition costs, especially when a company has legacy investments. Many circular models deliver their biggest return in the medium- or long-term, so linear approaches to investment for short-term returns often look more attractive than circular business models. It can be difficult for businesses to secure buy-in from their stakeholders if they are not aware of the long-term benefits of the circular economy. Businesses could address this issue with transparent internal strategic planning to set expectations of the timeline for achieving profits and planning investments accordingly.

For example, construction companies could protect themselves against future resource scarcity and rising prices by setting voluntary guidelines, such as using renewable sources of building materials and making this part of the long-term vision of the way they use and recycle materials. Going a step further and using buildings as banks to store materials can enable recovery of these materials in due course, but requires long-term planning to acknowledge the length of time a building is likely to be used.

Collaborate with other businesses, policymakers, and the informal economy.

Participation in pre-competitive collaboration in cross-industry and cross-value-chain networks can enable businesses to drive change that they cannot create on their own. Opportunities include leveraging industry cooperative networks and collaborating on specific issues that require systemic problem-solving, such as complex reverse logistics.

To create systemic solutions, overcoming the challenge of coordinating and aligning the incentives of actors along value chains is critical. For example, in the construction sector, a real estate developer that sells its building does not benefit from commissioning one with high energy efficiency while in use and with components that are reusable at demolition: the buyer (or possibly the tenant in the former case) will capture them. The car industry in India faces the additional problem of potential competition between vehicle manufacturers and the informal sector for the material streams and repair work, that is further enabled by the production of cars increasingly designed to be readily repaired and with components that can be remanufactured. In this case, incorporating existing informal sector repair and recycling activities can create benefits for both that sector and car

manufacturers. More generally, collaborative efforts that genuinely bring together actors from across the value chain can work to overcome these challenges.

Collaboration can take various forms, including industrial symbiosis, public-private agreements, R&D clusters, and voluntary industry initiatives. Opportunities for businesses to collaborate in specific areas are emerging in systemic change initiatives like the New Plastics Economy Initiative.²⁴³

Organisations in India, including the Confederation of Indian Industry (CII) and the Federation of Micro and Small & Medium Enterprises (FISME), have platforms that enable business to connect in order to collaborate and share knowledge. The Ellen MacArthur Foundation's Circular Economy 100 (CE100) is another example of a platform that can enable such collaboration, bringing together businesses, governments and cities, academic institutions, emerging innovators, and affiliates.

Invest in circular economy opportunities. While sizing and prioritising the value of investment related to the circular economy opportunities outlined in this report requires detailed analysis, the circular economy offers attractive opportunities for both businesses and financial institutions. Companies could moreover scale back investments in linear business models to avoid risks of exposure to greater market volatility and stranded assets.

As discussed above, circular models often involve transition costs (see also *Role of transition costs and investment*). Continued investment in linear business models and infrastructure increases such costs as it can lock the economy into ineffective systems that inhibit the emergence of circular alternatives. Businesses could integrate new sources of value creation into their scenario planning to explore the relative risks and benefits of circular models.

ROLE OF TRANSITION COSTS AND INVESTMENT

The strong economic rationale for the circular economy encourages reframing the discussion to focus on transition speed. That speed is determined by the costs of the transition, which includes investments in assets or new digital infrastructure, research and development, training, support to promote market penetration of new products, and transitional support for affected industries, education, and cooperation.²⁵²

While many circular economy efforts have been proceeding in India for some time, high transition costs have inhibited faster speed to scale. Some of these transition costs are higher than others, and digital opportunities with low marginal costs, like asset- and knowledge-sharing models or mobility route and access optimisation models, could move rapidly to scale.²⁵³

Capturing the long-term benefits of a circular economy and mitigating the risks of linear development require identifying priority initiatives that have short-term investment potential. Recent research found €320 billion of circular economy investment available to investors in Europe by 2025 and achievable with modest policy and industry action.²⁵⁴ **The opportunities for India outlined in this report require similar analysis to determine the right investments to make and the political and industrial action required to benefit from them.**

GOVERNMENTS CAN SET DIRECTION FOR THE TRANSITION AND CREATE THE RIGHT ENABLING CONDITIONS

Five recommendations could guide policymakers at national, state, and local/city levels in supporting the transition in the medium- and long-term.

Set direction and show commitment. Clear policies and communication can encourage private and public investment in relevant

research and business development. While scattered existing provisions and regulations include some circular economy principles, advancing the transition requires a coherent focus and systematic approach, including integration of circular economy ideas into existing government initiatives. Policies could, for example, provide targets and strategies. Clear and binding policies, laid out in a roadmap, would provide the visibility needed to coordinate infrastructure development and investment planning.

Lack of clear direction can hinder innovation toward circular models as businesses and research institutions would be less confident about directing investment towards specific technologies. An overarching circular economy strategy could build confidence to bring circular economy principles into education syllabuses and creating training opportunities that would align skills and knowledge in the future workforce.

Investing in research to develop economic solutions and building an evidence base can help overcome challenges associated with the high cost of new technology and negative public perceptions. For example, the Indian government is using policy to make clear that electric vehicles will be part of India's future. Such clarity encourages businesses to invest in research that will overcome barriers to the broad adoption or economic viability of electric vehicles, such as battery reliability or the cost of the technology, and therefore the vehicles.

To provide clear direction, governments could reduce barriers to the adoption of new business models. This could include aligning incentives to support circular business models and ensuring that governance measures demonstrate commitment by addressing non-compliance.

Strategies for cities could provide a framework and tools to assess both current linear activities and prospective circular economy activities in the city. Such tools could also support the creation of global networks for collaboration and data-sharing among cities.

Create enabling regulatory frameworks and remove policy barriers. Some current policies, typically focused on individual areas rather than taking a systemic view, cause unintended barriers to adopting circular business models. Detailed analysis of regulations in each sector – conducted with businesses and other relevant stakeholders – could identify these barriers and provide a basis for recommending policy changes that support circular economy opportunities.

Regulatory frameworks can provide positive stimulus for adoption of circular models through, for example, fiscal incentives. However, a lack of systemic approaches to policy creation can lead to misaligned incentives that work against, rather than for, circular models. For example, fertiliser subsidy schemes like the nutrient-based subsidy (NBS) have led to excessive fertiliser application ratios and subsequent decline in soil health,²⁴⁴ incentivising conventional methods rather than regenerative practices.

In the construction sector, the policy to provide housing for all by 2022 encourages the use of materials like concrete and brick in building permanent housing and neglects renewable or recycled materials.²⁴⁵ Likewise, building regulations or standards that do not permit or explicitly mention the use of renewable materials could lead construction companies away from using these materials.

Create platforms for multi-stakeholder

collaboration. Collaboration among stakeholders to address key issues is critical to achieve systemic change. For example, inroads to addressing India's solid waste management challenge could be made by connecting interested actors across value chains, including producers, municipalities, the informal sector, waste management companies, and research institutions.

Efforts to adopt circular business models could face the challenge of siloed thinking in parts of the value chain, preventing value capture elsewhere. Developing networks among businesses, governments, and education could foster collaboration on key issues and support systemic change. For example, R&D collaboration can overcome barriers to the viability of circular economy opportunities created by the lack of cost-effective technology.

For example, addressing issues related to solid waste management and material flows in cities requires involving all kinds of different actors, including producers, municipalities, the informal sector, waste management companies, and research institutions. Connecting those stakeholders through collaboration platforms can support effective flows of materials from the product design stage to the collection of products after use and their return for repair, reuse, remanufacture, and recycling.

Governments can play a key role in facilitating the flow of information among stakeholders. Information-sharing platforms can make it easier for businesses to share feedback with policymakers when policies prevent progress. For example, city strategies could provide platforms to connect local stakeholders and share learnings and experiences on a global scale. An association or an institution with government involvement – like the Chinese Circular Economy Association (CCEA)²⁴⁶ – can facilitate cooperation. The global C40 network works to empower cities to connect with each other and share technical expertise on best practices.²⁴⁷

In November 2015, the Ministry of Environment, Forest and Climate Change established the Indian Resource Panel to partner with other governmental ministries and private and public organisations to facilitate the use of recycled materials, act as a hub for resource efficiency, and bring policymakers the right policy and technology support.²⁴⁸ Digital India is driving initiatives, such as the website data.gov.in that is publishing governmental datasets, documents, services, tools, and applications collected by the government for public use.

Support circular models through public procurement and infrastructure. Using a circular procurement approach, public organisations could acquire goods and services in a way that achieves value for money throughout a product's use, while minimising material losses and adverse environmental impacts. Public procurement recommendations that support promising, scalable circular business models, from both emerging and established innovators, could help kick-start those models to stimulate their wider adoption in the market. Focusing infrastructure investments on infrastructure such as integrated post-use collection systems and sorting and reprocessing facilities could support circular economy activity and investment by the private sector.

For example, public procurement of building materials is governed by the schedule of rates (SOR), a list of products that government agencies can buy.²⁴⁹ These SORs include some recycled materials, such as new insulation products, but do not include recycled construction and demolition waste, of which India has a large and cheap supply. Updating procurement practices could remedy this situation.

Government investment strategies supporting circular economy activity can prevent cities from getting locked into less favourable and resource-inefficient infrastructure for the long term. Infrastructure is long lasting and can become a barrier to adopting circular models if circular economy principles are not applied from the start.

For example, in setting up a solid waste management system, it could initially seem strategic to invest in waste-to-energy infrastructure. While providing a source of energy, this approach prevents the capture of more value from materials by reusing and recycling them through an effective waste collection and sorting processes. A conflict for resources could arise if consideration is not given of the whole system from the outset, as high-value, high-energy materials would get

diverted from waste-to-energy plants feedstock streams and reduce their energy output. The high capital cost of the plants could also lead to lock-in to ineffective or obsolete infrastructure that subsequently stands in the way of making higher value use of solid waste streams.

Embed circular economy principles into education. Bringing circular economy principles into education, from school through to professional development, can equip learners with the right systems thinking skills and mindsets to become active shapers of a circular economy. Increased access to information, for example through open-access courses, helps bridge knowledge gaps, reduce scepticism, and increase awareness of the value of circular models.

Education defines how learners see the world and how they approach their working lives, so including circular economy principles could inform the aspirations of generations. Preparing the entrepreneurs, designers, engineers, procurement officers, and product managers of the future to completely rethink economic systems will allow them to be open for new models and create a more resilient economy for the long-term.

Education could build on systems thinking, which has a long tradition in India,²⁵⁰ and enable learning that creates broad understanding of the circular economy, resource flows, and systems. This can help overcome the barriers associated with siloed organisational structures, negative cultural perceptions, and reluctance to accept new models. Open source resources can further strengthen the education of the vast Indian population across the socio-economic spectrum and material could be made available in different languages and formats.

OTHER ORGANISATIONS CAN PLAY IMPORTANT SUPPORTING ROLES IN THE TRANSITION TO A CIRCULAR ECONOMY

Various other stakeholders, including universities, non-profits, and international organisations, can support businesses and governments in demonstrating the value of a circular economy. These organisations can also play a key role in connecting stakeholders to share information, case studies, and lessons learned and in stimulating discussions and problem-solving efforts to advance the adoption of circular economy models.

These organisations could also provide platforms to connect stakeholders working to overcome challenges associated with the transition. For example, the Circular Economy

Institute in France facilitates collaborative initiatives and information-sharing among prominent companies, scholars, associations, collectives, enterprises, research bodies, and government at various levels.²⁵¹

Participation in research and pilot projects can establish a knowledge base and proof points and play a role in representing the interests of groups like the informal economic sector to find systemic solutions that include these workers.

IN THE SHORT TERM, FURTHER STAKEHOLDER ENGAGEMENT AND RESEARCH IS NEEDED

The recommendations outlined above involve many stakeholders and require solid evidence of the benefits of circular economy opportunities in India. Preparing to act on those recommendations calls for engaging the stakeholders and conducting additional research. These initiatives would be most successful if led by people in India.

Create and maintain mechanisms for stakeholder dialogue. The initial insights in this report provide a solid basis for beginning to engage key stakeholders from business, policy, education, and non-profits on the vision of a circular economy in India. Their involvement would enrich further research efforts, as detailed below.

A dialogue on the vision would be critical to developing collaborative initiatives. Dialogue between policymakers and businesses, in particular, could be instrumental in creating effective enabling conditions for circular economy innovation, such as standards, skills-building, legal frameworks, and demonstrators.

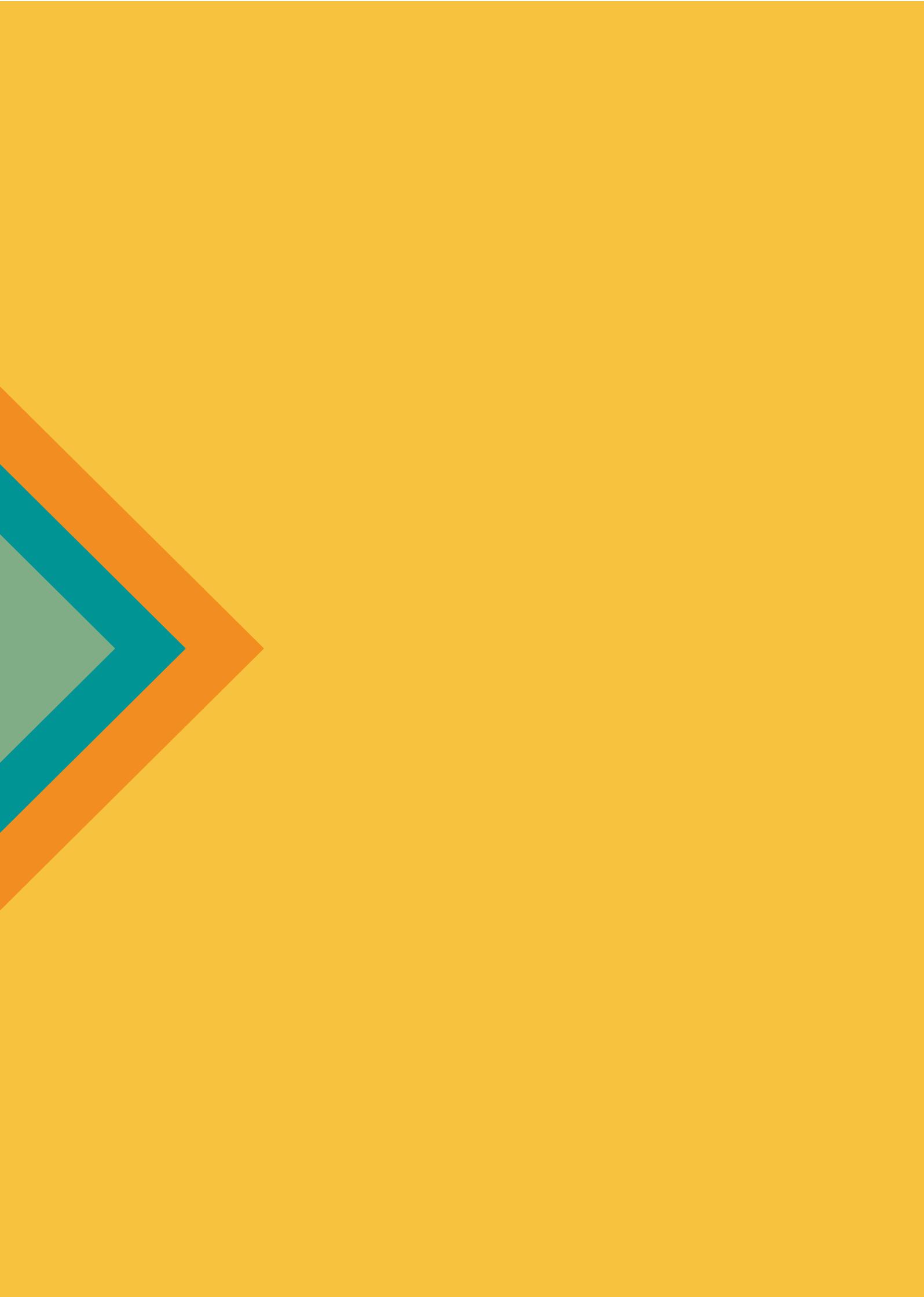
Identify knowledge gaps and build an evidence base. The analysis done for this report sought to provide an initial vision of the circular economy and its benefits for India. Many analyses exceeded the scope of this project and warrant further effort.

For example, detailed analysis of the current policy landscape, including collating and completing existing research, would be necessary to identify legal barriers and opportunities. Analyses to further qualify and quantify investment opportunities and transition costs and to explore other environmental externalities particularly relevant to India, such as pollution effects, and their economic impact need owners.

India is a large and diverse country. Many of the circular economy opportunities would vary greatly in relevance to, and impact on, different regions. State-level analyses, for example of the policy landscape or benefits, would be critical to securing engagement and launching the right initiatives.

APPENDICES





APPENDIX A: COMPARISON OF DEVELOPMENT PATHS TO 2050

CITIES AND CONSTRUCTION

In both scenarios, urban planning would loom larger in city development, but the circular scenario would foster collaboration and the integration of urban systems, including food and mobility, to create thriving cities. Current efforts to implement master plans in cities involve lengthy procedures that would struggle to keep pace with the speed of development required.

Initiatives like the Jawaharlal Nehru National Urban Renewal Mission (JNNURM) and the Smart Cities Mission would create more detailed urban plans and greater planning capacity. But limited integration with mobility systems would hinder India's ability to address urban sprawl and increasing traffic congestion or to free up land for affordable housing at scale.

The circular scenario would address these challenges by rethinking how urban systems operate and interact with each other and building future cities to ensure long-term prosperity, resource efficiency, economic viability, and human wellbeing.

Basic services for water, wastewater, and solid waste management would improve quality and access in both scenarios, but the circular scenario would capture significantly more value by keeping materials flowing through the system. On the current development path, initiatives to clean up cities, including the Swachh Bharat (Clean India) mission and AMRUT (Atal Mission for Rejuvenation and Urban Transformation), coupled with new solid waste management legislation, would improve waste management practices. Efforts would deliver waste and water services to all citizens in urban areas by 2050 and begin to integrate the informal sector into these systems. But linear approaches would lock cities into long-term infrastructure that lets valuable materials and nutrients leak out of the system.

In a circular scenario, infrastructure would minimise waste and effectively close nutrient loops. Technical materials would flow through cities, following a defined and monitored pathway from design to end of use. Informal sector workers would be fully integrated into and supported by the system, and full advantage would be taken of material value.

In both scenarios, a young, digitally savvy, urban workforce would embrace sharing and multi-use of space, but these practices would scale more rapidly in the circular scenario. Co-working spaces are gaining popularity in India, and this trend would continue. The co-working share of the U.S. office market is predicted to reach 2% by 2020. India would see co-working spaces account for as much as 5% of the office market by 2050.²⁵⁵

In a circular scenario, digital innovation in other systems, particularly food and mobility, would encourage more rapid adoption of shared working and living spaces than in the current development scenario. Spaces would be designed for sharing from the start, making the idea cost-effective while providing comfortable living conditions. In the circular scenario, 13% of residential spaces would be shared by 2050.

The current development path would stimulate building energy and water efficiency efforts. The circular development path would go further and create energy-positive buildings at scale. On the current development path, the ECBC and the GRIHA would encourage some adoption of energy and water efficiency in commercial buildings, but these codes are not mandated, are largely inapplicable to residential buildings or buildings that are not air-conditioned, and do not accommodate different building designs like passive cooling.

On the circular development path, circular design approaches would ensure the optimisation of water and energy use and would keep people comfortable with heating and cooling powered by renewable sources of energy. Regulation and new innovation would drive down costs of new technologies and lead to more rapid application of these approaches in the construction of new housing stock.

In both scenarios, technological advances and efforts to lower construction costs would increase modular production, but the circular scenario would also reduce waste by creating adaptable buildings and reusable components. Industrial production methods exist in the Indian construction industry but enjoy only a tiny market share. Less than 1% of construction uses modular or prefabricated techniques.²⁵⁶

On the current development path, government plans to address slum development and provide affordable housing would create demand for economical and rapid construction methods. Given the considerable construction activity needed and the technology to support more economic methods, the construction industry would see continued but slow adoption of modular techniques, possibly achieving market share of 19% by 2050. But modular buildings constructed without consideration of the end of use would not capture the full value of materials.

On the circular development path, India would reap the benefits of cheaper and faster construction of modular buildings. Construction approaches would ensure building durability through easy preventive maintenance and would enable easy disassembly or reconfiguration. Economical modular design would support the extensive self-building culture in constructing more durable, safe living environments. Modular construction could account for as much as 52% of new buildings by 2050.

On the current development path, the use of recycled materials in construction would increase slowly, while the circular scenario would close materials loops by using renewable materials and designing building components for easy disassembly to enable reuse or recycling. In the current scenario, replacement of finite virgin materials with secondary materials like construction waste and fly ash would increase, as policy would mandate their use in bricks and concrete. The need to construct new buildings would increase the demand for finite materials, such as sand, aggregates, and limestone. As materials became less easily accessible, materials costs would increase, and construction would continue to generate large amounts of waste.

In the circular scenario, recycled or renewable materials would replace construction materials like concrete and bricks that rely heavily on energy-intensive extraction and manufacturing processes. Policies would encourage a rapid increase in demand for recycled and renewable materials to replace most virgin materials. Alternatives to cement and bricks would account for 40% of construction materials by 2050, and another 41% would come from recycled sources.

Buildings applying circular design principles would serve as materials banks, supported by BIM to track materials. Shifting to renewable materials, where appropriate, combined with closing materials loops, would minimise negative environmental impact and maximise social and economic benefits.

FOOD AND AGRICULTURE

Regenerative agricultural production would increase in the current scenario but would dominate farming in the circular scenario.

On the current path, regenerative farming would gain market share (to about 10% of total agricultural production), but in a slow and limited way, bringing fresh, healthy produce to a niche premium market. On the circular path, regenerative farming would account for 70% of total agricultural production, saving as much as 97 tonnes of GHG emissions and 77 trillion litres of water, compared with the current path.

The Indian Council of Agricultural Research (ICAR) expects cultivation units to grow larger, with very few well-trained farmers producing in a highly mechanised environment by 2050.²⁵⁷ This could result in significant degradation of natural capital and loss of biodiversity, reducing the system's ecological resilience and long-term yield, especially in the face of water scarcity and climate change challenges.²⁵⁸

In the circular scenario, policymakers would review existing policies for unintended negative impact on resource productivity. A system structure based on multiple small-hold farmers would create product diversity (which translates into ecological diversity) that would build economic and ecological resilience to external shocks.

In both scenarios adoption of precision farming and other technology-enabled practices would increase. In the current development scenario such practices would mainly support large-scale conventional agriculture, whereas in the circular scenario they would support regenerative agriculture practices. On both paths, about 75% of agricultural production would tap technological advances to increase resource efficiency and yield. The current development scenario would focus on precision farming equipment and digital solutions to support highly resource-intensive and specialised agricultural production. The circular scenario would focus on high adoption of low-cost technology, especially cloud-based digital solutions that could scale easily to support many small farmers.

Knowledge- and asset-sharing solutions would loom large in the circular scenario. While asset-sharing platforms would play some role in the current scenario, they would be crucial in the circular scenario, giving small-hold farmers access to high-tech equipment on a pay-per-use basis. In both scenarios, penetration of knowledge-sharing platforms would grow, to 40% on the current path and 90% on the circular

path. These platforms would equip farmers to share traditional knowledge and practices and access new research insights.

In both scenarios, digitised supply chains would reduce food waste and the number of steps, but the impact would be significantly greater in the circular scenario. Supported by government initiatives transforming marketing channels,²⁵⁹ 40% of agricultural production would take advantage of this opportunity on the current path. On the circular path, government and the private sector would collaborate to create innovative channels boosting total penetration to 90%, better connecting small-hold farmers with customers, integrating supply chains, raising farmer income, and improving access to food.

Peri-urban and urban farming would increase in both scenarios but would enjoy systematic implementation and support only in the circular scenario. On the current path, urban farming projects of different shapes and sizes would appear sporadically across India. But supply chains would generally remain long and generate considerable waste. On the circular path, these projects would be part of a systemic approach to food production and delivery and integrated into urban planning policies to reduce transportation costs and waste.

The current scenario would see some progress on recovering nutrients from food waste, but not human excreta, while the circular scenario would see high rates of nutrient recovery from both sources. In both scenarios, composting and anaerobic digestion technology would improve, and better waste collection would have positive impact on nutrient recovery from food waste. On the current path, the recovery rate would be 40%. On the circular path, a systemic approach to waste management, including the separation of organic and non-organic waste, would bring recovery rates as high as 90%. Recovery of human excreta integrated into new and existing sanitation infrastructure would produce recovery rates of about 60% (compared with none on the current path).

MOBILITY AND VEHICLE MANUFACTURING

The current scenario would pursue development oriented around privately owned vehicles, while the circular scenario would create a diverse and integrated mobility system to meet increasing demand for mobility. The growth of the Indian economy would increase the per capita demand for mobility 133%, by 2050, on the current development path.²⁶⁰

Demand would increase only 114% on the circular path, as urban planning and virtualisation of work would reduce commuting.

Development of infrastructure in the current scenario would prioritise use of private vehicles, and these vehicles would account for 28% of annual passenger kilometres driven. The circular scenario would diversify transportation modes and create a very effective integrated mobility system, making the use of private vehicles almost irrelevant. Cars would account for only 20% of annual passenger kilometres driven. The integrated system would provide effective, low-cost mobility, delivered primarily by public transport and vehicles as a service. This system would decrease congestion and increase convenience.

While achieving limited success in the current scenario, vehicles as a service would become a popular choice in the circular scenario, integrated fully into a seamless mobility system and supported by effective mass transportation. Urban citizens would embrace vehicles as a service, valuing the access to vehicles at lower cost and the elimination of the hassles of owning and parking a vehicle.

Well-developed car-sharing schemes would enable convenient use of cars all over the city. These schemes would handle 61% of passenger kilometres driven per car, compared with 23% in the current scenario. Inexpensive, readily available ride-sharing schemes would increase the occupancy rate of cars to 3.3 occupants per vehicle, compared with 2.0 in the current scenario.

Technological innovation would win quick adoption, especially in the circular scenario. In the current scenario, technology adoption would happen principally at the vehicle level, as people embraced in-vehicle connectivity and autonomous driving to reduce congestion and accidents. This would amount to optimising products alone, rather than taking the broader mobility system into account.

In the circular scenario, technological innovation would enable the development of an integrated and multimodal transport system. This system would reduce reliance on private vehicles.

Use of electric vehicles would increase in the current scenario but would become mainstream in the circular scenario. On the current path, government incentives would give electric vehicles a 45% share of the fleet, but the quality and high cost of batteries and lack of charging infrastructure would keep them from becoming the new norm.

On the circular path, electric vehicles would enjoy wide adoption and would account for 72% of cars on the road. Charging infrastructure would be readily available, and manufacturers would improve and guarantee the reliability of batteries and fuel cell stacks.

In the circular scenario, unlike the current scenario, new business models and new approaches to car ownership would increase vehicle durability. In the circular scenario, vehicle manufacturers would team with car-sharing companies or would develop new business models that would extend their involvement with vehicles beyond their sale.

In the current scenario, vehicle durability would decrease, mainly due to fast-changing technologies and increasing vehicle complexity, in business models designed to profit only from selling new cars. In the circular scenario, the prospect of net material savings and higher profits would encourage efforts to make vehicles more durable. Vehicle design would accommodate reconditioning with new, higher-

performing engines, upgraded interior styling, and redesigned exteriors. Consequently, vehicles could stay on the road longer, driving 30% more kilometres than in the current scenario.

Looping of components and materials would increase in both scenarios but would result from a systematic, 'by design' approach only in the circular scenario. In both scenarios, regulations would improve the dismantling and recycling of vehicles. But in the circular scenario, vehicle manufacturers would collaborate with the recycling sector to loop materials back into their vehicles. In the circular scenario, manufacturers would also design for easy disassembly to ensure access to recycled materials and avoid volatility of raw material price. Car manufacturing would use 55% recycled materials, compared with 30% in the current scenario. Led by manufacturers who brought the once informal sector into the formal economy, parts remanufacturing would be widespread and trusted in the circular scenario.

APPENDIX B: APPLYING CIRCULAR ECONOMY PRINCIPLES IN OTHER EMERGING ECONOMIES

Due to their high rates of economic growth and rapid pace of societal change, it will be emerging economies that most affect the overall economic and environmental path the world takes in the coming decades. The level of adoption of circular economy ideas in these countries is therefore crucial to those ideas' global relevance.

The findings in this report provide insights relevant not only to India, but also to other emerging economies. These insights could inform investigation of circular economy opportunities in those markets. Any effort to analyse circular economy opportunities in other geographies would, however, require developing approaches tailored to their unique social, political, economic, and environmental context.

Many circular activities are proceeding in emerging markets, but they are predominantly small in scale and focused on the end of value chains. These activities include reuse of products and materials, recovery of biological nutrients, high utilisation of infrastructure and vehicles, and traditional, regenerative farming methods.

It is important to acknowledge that economic growth to date has largely taken a linear path, and desire for economies of scale is likely to push emerging markets further in that direction by encouraging adoption of models embraced by mature markets. Following this path would quickly undermine current circular activities. Emerging markets should scale and professionalise those activities in order to make them central to their value creation strategies and launch new projects that could become mainstream.

As emerging markets have yet to build or organise many systems, they could move directly to a circular economy. Mature markets have many systems and much infrastructure designed to function in a linear economic model that are not easy to transition to a circular economy.²⁶¹ Examples include cities optimised for car transportation, incineration infrastructure, and business development based on increased sales volume and associated overcapacity (vehicles, appliances, etc.). By adopting a circular economy development path today, emerging economies could avoid such linear lock-ins, creating long-term competitive advantage.

Digital enablement would play a key role in capturing circular economy opportunities in emerging markets. Digital tools enable managing and sharing high amounts of data. This delivers valuable benefits, including better understanding of material flows; support in making complex decisions, such as materials choice or optimisation of business models; knowledge- and information-sharing platforms.

While useful in any market, digital solutions loom especially large in emerging markets because their marginal costs are low. Solutions could therefore be adopted widely and enable effective decentralised models with limited investments.

The informal economy plays a significant role in emerging markets. Much economic activity happens in an informal, undeclared way. This encourages the resourcefulness and entrepreneurship that transform circular economy principles into practice but also produces information gaps and makes the implementation of standards difficult.

More decentralised models of transitioning to a circular economy, with small businesses and entrepreneurs playing key roles, would likely make good use of the labour force. However, the issue of how to engage informal workers as part of the transition to a circular economy requires further study.

Successful implementation of circular economy principles in emerging markets would require addressing the perceptions of the growing middle class. Many of the interviews and discussions that inform this report highlighted that implementation of a circular economy model in emerging markets would face a challenge in the perception that linear consumption patterns, such as product ownership or access to air conditioning, signal prosperity.

Successful circular economy initiatives would require understanding and addressing this challenge and ensuring, in the long-term, that circular economic models were not only more effective for the wider society but also desirable at the individual level. This would, in turn, require effective operations (e.g. convenient and cost-effective business models) and communications (e.g. information and marketing campaigns).

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About the Ellen MacArthur Foundation

The Ellen MacArthur Foundation was established in 2010 with the aim of accelerating the transition to the circular economy. Since its creation the charity has emerged as a global thought leader, establishing the circular economy on the agenda of decision makers across business, government and academia. The charity's work focuses on four interlinking areas:

EDUCATION

Inspiring learners to re-think the future through the circular economy framework

The Foundation is creating a global teaching and learning platform built around the circular economy framework, working in both formal and informal education. With an emphasis on online learning, the Foundation provides cutting edge insights and content to support circular economy education and the systems thinking required to accelerate a transition.

Our formal education work includes comprehensive Higher Education programmes with partners in Europe, the U.S., India, China and South America, international curriculum development with schools and colleges, and corporate capacity building programmes. In the informal education arena our work includes the Disruptive Innovation Festival, a global online and face-to-face opportunity to explore the changing economy and how best to respond to it.

BUSINESS AND GOVERNMENT

Catalysing circular innovation and creating the conditions for it to flourish

Since its launch, the Foundation has emphasised the real-world relevance of its activities and understands that business innovation sits at the heart of any transition to the circular economy. The Foundation works with its Global Partners (Cisco, Google, H&M, Intesa Sanpaolo, NIKE Inc., Philips, Renault, and Unilever) to develop circular business initiatives and to address challenges to implementing them.

In 2013, with the support of its Global Partners, the Foundation created the first dedicated circular economy innovation programme, the Circular Economy 100. Programme members comprise industry leading corporations, emerging innovators (SMEs), affiliate networks, government authorities, regions and cities. The CE100 provides a unique forum for building circular capabilities, addressing common barriers to progress, understanding the necessary enabling conditions, and piloting circular practices in a collaborative environment.

INSIGHT AND ANALYSIS

Providing robust evidence about the benefits of the transition

The Foundation works to quantify the economic potential of the circular model and develop approaches for capturing this value. Our insight and analysis feeds into a growing body of economic reports highlighting the rationale for an accelerated transition towards the circular economy, and exploring the potential benefits across different stakeholders and sectors.

The Foundation believes the circular economy is an evolving framework, and continues to widen its understanding by working with international experts including key thinkers and leading academics.

COMMUNICATIONS

Engaging a global audience around the circular economy

The Foundation communicates cutting edge ideas and insight through its circular economy research, reports, case studies and books disseminated through its publications arm. It uses new and relevant digital media to reach audiences who can accelerate the transition, globally. In addition, the Foundation aggregates, curates, and makes knowledge accessible through Circulate, an online location dedicated to providing up to date news and unique insight on the circular economy and related subjects.



About the United Nations Conference on Trade and Development

The United Nations Conference on Trade and Development (UNCTAD) supports developing countries to access the benefits of a globalized economy more fairly and effectively. UNCTAD does so by equipping them to deal with the potential drawbacks of greater economic integration, supporting countries through the provision of analysis, consensus-building, and technical assistance. This helps them to use trade, investment, finance, and technology as vehicles for inclusive and sustainable development. UNCTAD serves the citizens of the 194 countries that make up the organization. Together with other UN departments and agencies, UNCTAD measures progress by the Sustainable Development Goals, as set out in Agenda 2030. Its goal is prosperity for all.



About Climate Works Foundation

Philanthropy has a critical role to play in solving the climate crisis. ClimateWorks Foundation helps foundations and climate leaders come together to be more strategic, efficient, and effective in their response to global climate change. We are a collaborative team of researchers, strategists, and grant-makers committed to our mission to mobilize philanthropy to solve the climate crisis and ensure a prosperous future. For more information about our programs, grant-making, and partnerships, visit www.climateworks.org.



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