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CATALYSTS FOR TRANSITION TO CIRCULAR ECONOMY SOLUTIONS IN THE BIOWASTE MANAGEMENT SECTOR IN INDIA

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Introduction

India is the fifth largest economy in the world and is growing fast to be in the top three global economies. India's economic growth is unprecedented, with about a 10% gross domestic product (GDP) growth rate (Asian Development Outlook [ADO], 2021). While industrialisation is growing at an accelerated rate, India faces three distinct challenges: (1) to provide a continuous energy supply to industries, (2) to reduce greenhouse gas (GHG) emissions to tackle climate change, and (3) to manage waste generated with the industrial and population growth. In response to these challenges and the diminishing and limited resources of traditional fuels such as natural gas, petroleum, and coal, there has been a need to develop an economy around biofuels.

Post–Paris Agreement in 2015, biofuels have gained significant attention around the globe since they are considered one of the most sustainable and environment-friendly forms of energy (Joshi et al., 2017). Countries have created national policies to motivate biofuel production and its usage in their countries. India also has its own National Policy on Biofuel (NPB), which was last updated in 2018. The NBP of India states, "biofuels are fuels produced from renewable resources and used in place of or in blend with diesel, petrol or other fossil fuels for transport, stationary, portable and other applications" (NPB, 2018, p. 15). The policy categorises biofuels into three generational categories:

1 First generation (1G): "Basic Biofuels" made of ethanol from molasses from non-edible oilseeds;
2 Second generation (2G): "Advanced Biofuels" – ethanol manufactured from municipal solid waste (MSW) to drop-in fuels; and
3 Third generation (3G): Bio-CNG, which is defined as a "purified form of bio-gas whose composition and potential energy is similar to that of fossil-based natural gas and is produced from agricultural residues, animal dung, food waste, MSW, and sewage water" (NBP, 2018, p. 15).

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In this chapter, we limit our focus to Bio-CNG production aspects in India, as it is a recent development and requires more in-depth analysis. The total Bio-CNG production in India, even though it has been an agrarian economy for a long time, is only 2.07 billion m^3/year, despite the massive potential of 29 to 48 billion m^3/year (Mittal et al., 2018). There is a vast, untapped Bio-CNG market in India, which needs proper utilisation of resources to generate higher levels of Bio-CNG production in India. To address this issue, a Bio-CNG plant has been built in the city of Indore in central India. As of 2022, this plant will be Asia's largest Bio-CNG manufacturing unit, producing 17,000 kg of Bio-CNG and 100 tonnes of organic compost from 550 tonnes of organic solid municipal waste per day (Press Information Bureau, 2022b). Further, the Indian government promises that 75 municipalities across India will receive similar Bio-CNG plants within the next two years (Press Information Bureau, 2022b). This large-scale transition uses a circular economy (CE) model to focus on using abundantly available waste, which is defined as solid waste, sludge waste, agricultural waste, and biodegradable waste. Also, this CE transition is creating a huge paradigm shift in multiple stakeholders that contribute to this circular economy.

Recent studies indicate that the use of biomass through using sustainable CE of waste for energy production can reduce GHG emissions (Kapoor et al., 2020). CE has emerged as a business model that integrates economic activity with environmental well-being for sustainable development (Murray et al., 2017). This emphasises redesigning processes and recycling waste materials to promote more environmentally friendly business models (Pearce & Turner, 1990), shifting away from the traditional waste management system in a linear economy. The traditional philosophy of efficient industries and economies worldwide has revolved around produce-use-dispose since the industrial revolution over the last century (McDonough & Braungart, 2010). Today, the 'cradle-to-grave' model (McDonough & Braungart, 2010) is still followed, creating a massive issue regarding waste management. For a country like India, a CE provides an in-depth industrial and economic development solution by managing waste and producing Bio-CNG.

As far as CE action areas are concerned, bioenergy and Bio-CNG are two fields that lack comprehensive analysis (Winans et al., 2017). Furthermore, in the Indian context, many articles and scientific journals have been written on several production and environmental opportunities and technical issues associated with biofuel generation (Dwivedi & Sharma, 2014; Joshi et al., 2016; Luthra et al., 2015; Mittal et al., 2018), but a few have focused on the business model and especially catalysts for such business models that support an economic transition to the use of biofuels through waste management for renewable energy generation (e.g., Goyal et al., 2018; Jonker et al., 2017; Rogge & Reichardt, 2016). To have a successful business model transition, India needs to understand which catalyst promotes CE to both manage large waste and manufacture Bio-CNG.

The primary aim of this study is to identify the catalysts of the transition to a CE for waste management by utilising waste for Bio-CNG production in the Indian context**.** To achieve this aim, we conducted 27 semi-structured interviews with the identified stakeholder group members to understand why they want to contribute to CE for Bio-CNG production. Specifically, we analysed how different factors serve as catalysts in the creation of an ecosystem that supports a CE for waste management and Bio-CNG production in the Indian context. The results show that there are six major catalysts that contribute to the development of CE in India that support efficient waste management for Bio-CNG production.

The contributions of this chapter are threefold. First, it introduces all the catalysts that are active in CE initiatives so India can create a business model that revolves around waste management for Bio-CNG production in the Indian context. Second, this chapter investigates the need for different stakeholders to participate and impact on circularity within the Indian Bio-CNG production process through waste management, offering yet another perspective on the literature with an emphasis on synergies based on different stakeholders' needs. Third, the study's focus on India and its waste management and Bio-CNG manufacturing industry contributes to the growing body of research on this topic coming from emerging economies.

The study presented in this chapter is organised into five sections. The current section presents the motivation and need for this study. The next section reviews relevant literature to understand the Indian context of waste management and the need for CE. After this, we describe the proposed methodology for this research with a description of data analysis. The results are presented in the following section and the last section presents a discussion of this study's findings and concludes the chapter.

The Indian context for waste management

Globally, the emission from the waste sector ranks low, which can be further managed with effective means (Koop & van Leeuwen, 2017). But in India, due to the population size and the waste management sector, waste emissions contribute to about 4% of India's total GHG emissions (Kolsepatil et al., 2019). These emissions come from municipal solid waste, agriculture, domestic, and industrial waste. As a result, waste generated has enormous potential as a large-scale alternative energy source through biofuel production, such as Bio-CNG. The waste management sector is divided into urban and rural segments. The urban sector is well organised and integrated with the local municipal bodies. The biowaste generated in the urban sector comes from places such as household, retail, and industrial wastes, which are collected by municipalities. The rural sector is not yet organised and generates multiple forms of agricultural waste.

The national-level composition of India's waste management profile is a concern both from a CHG emissions perspective and an opportunity to contribute to green energy production in the country (Table 6.1). A report by the Ministry of Environment, Forests and Climate Change

Table 6.1 Energy potential mapping from waste in India

SN	*Sectors*	*Energy potential – MW*
1	Urban solid waste	1,247
2	Urban liquid waste	375
3	Paper (liquid waste)	254
4	Processing and preserving of meat (liquid waste)	182
5	Processing and preserving of meat (solid waste)	13
6	Processing of fish, crustaceans (liquid waste)	17
7	Vegetable raw and processed (solid waste)	592
8	Fruit processing (solid waste)	21
9	Fruit raw (solid waste)	203
10	Milk processing/dairy products (liquid waste)	24
11	Maise starch (liquid waste)	47
12	Tapioca starch (solid and liquid waste)	53
13	Sugar (liquid waste)	49
14	Sugar press mud (solid waste)	200
15	Distillery (liquid waste)	781
16	Slaughterhouse (solid and liquid waste)	315
17	Cattle farm (solid waste)	862
18	Poultry (solid waste)	462
Total potential of energy (MW)		5,697

in 2021)states that India generates about 65 million tonnes of waste annually, including organic waste and recyclables such as paper and plastics (Ministry of Housing and Urban Affair, 2021). As per the Standing Committee on Urban Development Report (SCUDR) among this waste, 45–50% is biodegradable, 20–25% is recyclable, and 30–35% are classified as inert or debris (Ministry of Housing and Urban Affair, 2021). Out of this entirety, approximately 75% gets collected, and about 30% of this collection gets processed. Thus, increasing waste adds an environmental burden if it is not adequately treated, increasing the risk for major future climate concerns as waste production increases by multifold in the near future.

These waste management challenges have placed pressure on the Indian government, but they have also created a potential opportunity to drive energy production forward. It is expected that the use of waste in energy production, such as Bio-CNG, will reduce the import of fossil fuels to India and resulting from this, a reduction of carbon emissions into the atmosphere is expected, thereby potentially reducing global warming. It is also expected to create new jobs (Raza et al., 2011). India is committed to a "reduction in energy emissions intensity by 33%-35% by 2030 and the share of non-fossil fuel-based capacity in the electricity mix is aimed at above 40% by 2030" (NPB, 2018; p. 14). However, India already achieved this target in November 2021 and announced this accomplishment at the COP 26 meeting in December 2021. Consequently, India revised its targets to a 50% share of non-fuel-based capacity by 2030. In October 2021, to achieve this new target, the government of India (GOI) launched the second phase of the Swachh Bharat Mission-Urban 2.0 (SBM-U 2.0). This new initiative kicks off the implementation of the SBM-U 2.0 plan to make all cities in India garbage-free, which directly supports the integration of the waste management system with the cities' energy needs through Bio-CNG production (Departmentally Related Standing Committees, 2019). Along with this, GOI has initiated the second phase of the Atal Mission for Rejuvenation and Urban Transformation (AMRUT 2.0) for capacity building to reduce, reuse, and recycle in urban spaces. These types of initiatives open possibilities for transitioning from linear to circular economies. These proposed initiatives are directly linked to the municipal waste collection system and cater directly to the waste management needs of the urban sector in India. While waste management in urban India is being addressed to a large extent, waste management issues in the rural sector are under-addressed.

Challenges in waste management for the rural sector

Rural areas remain neglected in waste management. In the past, GOI had heavily endorsed small-scale biogas plants, promoting their use for biogas. Most of these projects were off-grid applications, and most gasifiers were limited to individual households. In the 1990s and early 2000s, four million family-sized biogas installations were installed in India (Raza et al., 2011). The Ministry of New and Renewable Energy (MNRE, 2022) estimated that the annual capacity to produce biogas could reach 17,340 million m^3, which is sufficient to install approximately 12 million family-sized biogas plants (Raza et al., 2011). Since these initiatives were primarily off-grid, such biogas production did not contribute much to the large economy or national energy production or reduce the dependence on fossil fuels (Gotmare & Nair, 2019). However, this initiative was not financially viable, and the output was insufficient for local consumption (Mittal et al., 2018).

Another issue with small-scale biogas plants was the need for a constant supply of raw material for the biogas generation. Such family-owned biogas production units were heavily dependent on agricultural waste. Agriculturally based raw materials are seasonal related to agricultural harvest cycles (Kimothi et al., 2020). Harvest cycles are not a continuous process; hence, they are not heavily dependable for the continuous production of biogas. Thus, this model is commercially unviable in a regional or local model that does not support an economy of scale or the larger national economy (Gotmare & Nair, 2019). The Indian government implemented many small-scale projects to supply renewable energy to rural areas (TERI, 2010). However, such undertakings were made with seemingly little effort to understand the needs of rural India. The rural population's perceptions and attitudes toward these bioenergy resources had not been thoroughly investigated in the agricultural sector, thus the so-called 'felt needs' were never assessed, but the so-called 'real needs' were assigned (Raza et al., 2011).

Waste management in urban cities – Example from Indore

The rapid increase in population has made municipal solid waste management an increasingly significant activity in the urban areas of India. Among the numerous responsibilities of municipal corporations and local urban bodies are the reduction and efficient handling of solid waste. To achieve a CE in urban cities in India, waste source separation plays a crucial role in sustainable and integrated municipal solid waste management (MSWM). Even so, uncontrolled and open waste dumping continues to be an unofficial practice in many cities, where mixed waste is received without any preparation for disposal (Dickella Gamaralalage et al., 2022). However, this practice is changing in many cities such as Indore, Pune, Surat, Bangalore, and other cities across the country. Next, we briefly describe the change in Indore.

The city of Indore achieved 100% source separation and a door-to-door waste collection system within a short, two-year time period (2015–2017) (Kanojia & Visvanathan, 2021). Under the government's Swachh Bharat Mission's (SBM) Swachh Survekshan Competition, the city received the national award for India's Cleanest City in the over one million population category for six consecutive years (2017–2022). The previous MSWM provision in Indore Municipal Corporation (IMC) was inadequate, which resulted in the city being one of the dirtiest in the region until 2015 (Indore Municipal Corporation [IMC], 2019). Residents discarded domestic waste at will, community bins overflowed due to a lack of waste collection, and stray animals roamed the streets freely; citizens had continued to demand improved waste collection services. Ultimately, these individual citizens' concerns led to the implementation of source separation; in response, the IMC adopted the Solid Waste Management Bylaw 2018 (Ghosh, 2017, 2020). The source separation of waste created an ecosystem for investors to invest in a large-scale Bio-CNG production unit in Indore. Since February 2022, this Bio-CNG plant operates on 100% wet waste. This plant is built on PPP mode, from which IMC will receive yearly revenue of one crore rupees (approximately USD$121,066). Additionally, the city will purchase 50% of the Bio-CNG produced daily; this will support 400 buses that Indore can run on the gas generated from the Bio-CNG plant.

Potential of the circular economy as a solution

The modern Bio-CNG technology-led production are large-scale business units, which are driven by innovation and profitability. Continuous production of Bio-CNG involves many actors and entities in the value chain. If the rural sector is integrated in the value chain of the Bio-CNG production, then the waste management in India goes one step further using a CE for efficient energy production throughout waste management. The introduction of CE as a business model for energy production through waste management represents a significant paradigm shift in the business model for all stakeholders. Businesses and entrepreneurs realise a market that both needs to be addressed and has economic potential. This realisation is at the heart of the current understanding and valuation of Bio-CNG and resources that can be acquired for production through waste management. The potential benefits of Bio-CNG include efficient management of waste, which serves as raw material, and the reduction of greenhouse gases, which replaces fossil fuels. This business model has secondary benefits, such as the restoration of soil productivity and reclaimed land by using manure generated after Bio-CNG production. Biomass from biowaste is an abundant and underutilised resource, which still needs to be utilised more effectively as a commercial and social resource. Thus, the paradigm shift calls for regime transition (Loorbach et al., 2017) toward CE for Bio-CNG production scalability, which calls for decoding the catalysts characterised by social forces, technological changes, and power relationships among stakeholders.

To achieve the aim of finding the catalysts, we use the concept of the catalyst with an interpretation of an agent to sustainability transformation for the long-term development of society with enhanced human well-being built on environmental accountability and protection (Smith et al, 2010). For this study, we observed catalysts as a form of 'initiator' or agent that increases the speed and rate of change or transformation. However, the catalyst creates a reaction in the development system that leads to economic activities reaching a self-sustaining threshold. Thus, this chapter assumes a catalyst as an 'enabler' to execute the development in a disciplined manner. The capacity of catalysts to influence the system depends on their ability to work as a 'visible hand' and an 'invisible hand' (Köhler et al., 2019). For example, government tax benefits have been a known catalyst for economic activity development in the state, which acts as a visible hand in the initial years but becomes an invisible hand or absent over time (Erlinghagen & Markard, 2012).

Methodology

This study used qualitative methodology to analyse the empirical data (Silverman, 2005) to identify the catalysts. The qualitative approach allowed an understanding of the catalysts that is mapped through the responses of different stakeholders (Creswell et al., 2007). Semistructured interviews were performed to collect data. This data was collected to understand the participants' unique perspective rather than a generalised understanding of the phenomenon (McGrath et al., 2019). The responses to the interviews allowed us to understand the factors that function as catalysts aligning with the CE approach. We were especially interested in providing our interviewees with the opportunity to describe their motivations and perspectives (Eisenhardt, 1989; Patton, 2002) as active participants in CE and in identifying the catalysts for the transformation of the industry.

Braun and Clarke (2006) suggest the use of thematic analysis (TA) for interpretive thematic outcomes, a widely used method for interpreting and analysing patterns of meaning or "themes" in qualitative data. By drawing on interviewees' insights, we can identify broader themes and connections among the actors involved in the transition, as outlined by Yin (2009). Although some argue that TA should not be considered a research methodology as it focuses solely on analysing existing data, it is still a valuable tool to draw on a range of qualitative analysis techniques, including qualitative content analysis, grounded theory, and narrative analysis (Wæraas, 2022).

By leveraging the power of TA, we could identify and interpret patterns of meaning or 'themes' in qualitative data in a robust and effective manner. Wæraas (2022) highlights the value of TA as an inductive-based analysis approach that is grounded in transparency and the data, rather than being theory-driven or deductive. To avoid this criticism by Wæraas (2022) and with the intention to identify themes or catalysts and not construct a theory, we used a three-stage data analysis model (Gioia et al., 2013) for TA to maintain data integrity and generate first-order terms directly from the data, before moving on to identify second-order themes. Throughout this process, we assemble terms, themes, and dimensions into a clear data structure that facilitates systematic coding and conceptualisation of emerging themes as catalysts for CE, with complete transparency.

Data collection

Industry experts nominated the interviewees or the segment of stakeholders. We contacted and interviewed two industry experts, an academic researcher who studies the technical side of Bio-CNG production, and the production head at one of the newly constructed Bio-CNG plants. Once we connected with these two experts, we mapped the stakeholders who directly and indirectly contributed to the Bio-CNG production through waste management. We carried out purposeful sampling (Patton, 2002; Suri, 2011) to identify the interviewees representing various stakeholder actors of the ecosystem. This process ensured that respondents are sufficiently aware about the Bio-CNG production and the Bio-CNG market (Robinson, 2014), and they are also available (Creswell et al., 2007) in the study.

We started the interview process with the first two mentioned experts to map the entire value chain of Bio-CNG production and to understand their perspectives on the catalysts that promote a CE in India. We started using the snowballing technique to identify our next interviewee in the data collection procedure (Parker, 2019). We interviewed 27 individuals engaged as policy-makers, entrepreneurs, operators, householders, farmers, and industry experts. The details of all interviewees are shown in Table 6.2. The interviews ranged from 21 to 55 minutes in length. The

Table 6.2 Details of the interviewees

S. No.	*Title (Gender)*	*Interview type*	*Interview length*
1	Entrepreneur 1 (Male)	Video Call	40 min
2	Entrepreneur 2 (Male)	In Person	25 min
3	Entrepreneur 3 (Male)	Video Call	47 min
4	Researcher 1 (Male)	In Person	45 Min
5	Researcher 2 (Male)	Video Call	42 Min
6	Operator 1 (Male)	Video Call	34 min
7	Operator 2 (Male)	Video Call	39 min
8	Operator 3 (Male)	Video Call	29 min
9	Operator 4 (Male)	Video Call	30 min
10	Farmer 1 (Male)	In Person	38 min
11	Farmer 2 (Male)	Video Call	55 min
12	Farmer 3 (Male)	Video Call	44 min
13	Farmer 4 (Male)	Video Call	49 min
14	Farmer 5 (Male)	Video Call	23 min
15	Retail Juice Shop Owner 1 (Male)	In Person	26 min
16	Retail Juice Shop Owner 2 (Male)	In Person	25 min
17	Small Restaurant Owner 1 (Male)	In Person	21 min
18	Householder 1 (Female)	In Person	28 min
19	Householder 2 (Female)	In Person	24 min
20	Householder 3 (Female)	In Person	26 min
21	Householder 4 (male)	In Person	28 min
22	Householder 5 (male)	In Person	25 min
23	Municipal Officer	In Person	25 min
24	Policy Expert	In Person	22 min
25	Business Manager 1	In Person	37 min
26	Business Manager 2	Video Call	41 min
27	Industry Expert	Video Call	35 min

interviews were conducted both in languages in English and Hindi to capture the technical and contextual understanding. Out of 27 interviews, 11 interviews were conducted in Hindi capturing stakeholders such as farmers, retail juice shop owners, a small restaurant owner, and a few householders. All interviews were auto transcribed through artificial intelligence (AI) and manually verified. For the transcriptions in Hindi, interview content was translated in English through an electronic translator and then manually verified by a language expert. The complete transcription of 27 interviews was 254 pages in length. We continued the data collection until it was observed that there are repetitive responses in the interview indicating that we had been close to theoretical saturation (Locke, 2001), although any specific number of interviews is not a decisive factor for a theoretical interpretation of complete data saturation (Eisenhardt, 2021).

Data analysis

We used Atlas.ti (version 9) as the data analysis tool. We started the data analysis by reading the interview transcripts and labelling the data with initial thoughts and concepts. Then, after the initial analysis, we performed the final three-stage analysis as described next. Although the description is linear and chronological, the analysis was iterative.

Based on Gioia et al. (2013), the first stage of analysis involves creating a deeper foundation for developing detailed descriptions. First, we identified parts of the interviews related to the interviewees' understanding of their position in the value chain for creating a CE for Bio-CNG production. We analysed the data with an awareness of the perceptions of various stakeholders in the value chain. We compared and compiled different data segments for developing the first-order concepts, and identified differences in stakeholder perceptions as shown in Figure 6.1.

In the second stage, we compared the first-order concepts and started to group them based on common themes. During this stage, we identified practical issues that support the creation of a CE in India related to waste management through Bio-CNG production. We observed how different stakeholders from their position in the value chain have different perceptions and topics that help them to be part of the CE or push them further away from the CE value chain.

In the third stage, we integrated the categories for the previous two stages to identify the catalysts for developing a CE in Bio-CNG production. During this analytical process, we identified six catalysts that support and initiate the development of a CE for Bio-CNG transition in India through waste management. Figure 6.1 shows the complete data structure of the data analysis.

Identified catalyst in the Indian context

Six main catalysts emerged that influence the formation of CE for developing and producing Bio-CNG production for waste management in India. The identified catalysts are: societal transformation, policy change, business demands, technology and innovation, profitable production, climate change, and sustainable farming. We present the findings in a linear sequence. These catalysts can be interrelated, and their synergy makes it possible to create an ecosystem based on a CE for biowaste management.

Transforming society

Stakeholders such as residents, professionals, academics, and policy experts have experienced social sensitivity and a systems thinking approach towards waste management transformation in society. For example, the city of Indore in central India is located in an industrial belt and is a

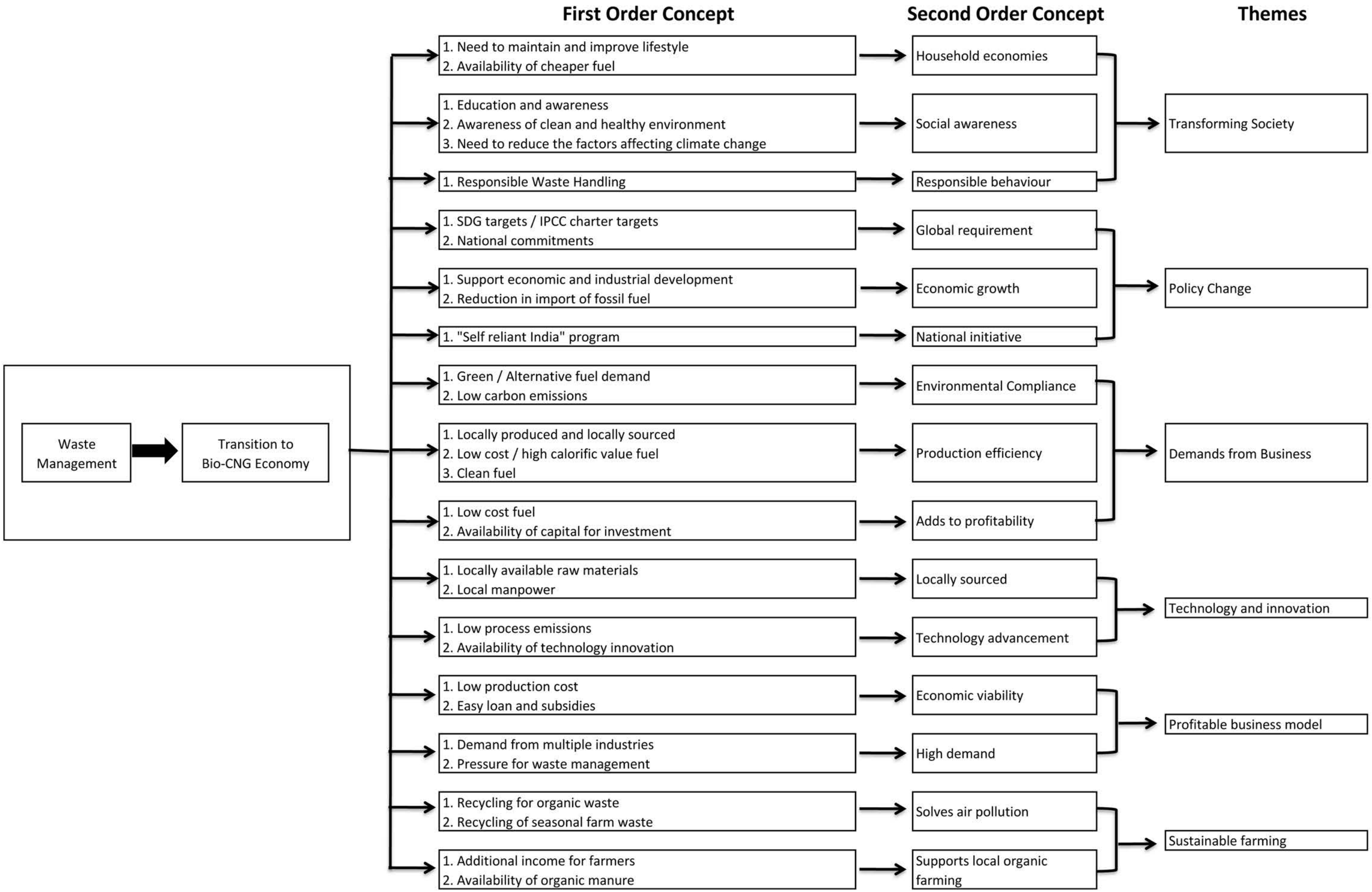

Figure 6.1 Identified catalyst framework in biowaste management in India.

densely populated city; its waste management systems were implemented with significant efforts in design, planning, and execution. A municipal officer had observed the need to empower the field workers and protect them from undue pressure of households with higher social status. The policy modification helped municipality workers to not accept the unsegregated waste from any household, irrespective of social status. Over time, the community started accepting the change.

> We now have stricter guidelines for waste managers, and our employees are trained to segregate the waste. We have also seen good response from the households […]. This was a challenge initially but the new policy on protecting municipality workforce helped us […], not every householder supports us, but many of them segregate their waste, and this is a good start. This is only an example of transition of society, but this is possible everywhere in India with sincere efforts by officials.
>
> (Municipal Officer, respondent 23)

While society stakeholders are well informed about the environmental impact, perceived benefits, lifestyle changes, and other direct or indirect benefits and need to change to a better waste management system was felt, but the path to the transition of society was unidentified. The waste management offered the opportunity to create economic value and Bio-CNG became a clean and locally produced commodity and the city Indore was branded as a clean city.

> It is a matter of pride for Indore to win the Cleanest City of India for consecutively six years due to the behavioural change of society. Citizens are aware now. They are educated or not, it does not matter but they appreciate the change and concerned to follow rules.
>
> (Retail Juice Shop Owner 1, respondent 15)

In another city in north India, Kanpur, which is an industrial city and one of most dense cities in terms of population, one of the respondents (Household 2) indicated his concerns about increasing dirt in the city, as well as the health and hygiene issues due to piles of waste.

> I would be happy if municipality could reuse the pile of waste being dumped in the peripheries of the city. It is not hygienic, and it is not good for health. […]. I am aware how things are developing in Indore. We should learn from them and create social pressure to influence the administration for change.
>
> (Household 2, respondent 19)

The social awareness and sensitivity that we define as 'transformed society' is observed as a catalyst because it creates peer pressure and force of change in social groups towards sustainability, in response converting the unsustainable into a CE model.

Policy change

Policy and regulations can push transformative institutional change (Kivimaa & Rogge, 2022) towards a sustainable transition. India has transitioned from protesting global environmental policies to actively shaping these policies at political leadership levels. Such an approach has led to a sustainable business model and transitioned into a stable CE model that had not been validated clearly in past research in India. However, one respondent reflected on how recent policy updates have made a contribution towards the market transition.

> We have not seen much policy and regulatory change with institutional mechanism to deliver in past. But now it's different. To honor its international commitments at the Paris Agreement, the government of India had to make several policy adjustments, institutional structuring, and supportive environment for business. The government created specific programs such as Swachh Bharat (Clean India) and Atma Nirbhar Bharat (Self Reliant India) which includes waste management and set specific targets to achieve.
>
> (Policy expert, Ministry of Petroleum and Natural Gas, respondent 24)

A respondent in the helm of policy cycle in the ministry of petroleum and natural gas observed how a national program is designed and delivered in a strategic way. The ministry develops national programs, which are rolled out as plans, while the responsible institutions take the responsibility of both the delivery and the continued performance of the program. This approach is well defined in terms of responsibility of each institution involved for effective policy-driven changes.

> Major focus has been on generating energy from waste like municipal solid waste (MSW), municipal liquid waste (MLW), farming waste, and farm produce targeted to produce biofuel under Swachh Bharat Mission.
>
> (Industry Expert, Chamber of Commerce, respondent 27)

> In the year 2015 at COP 21 meeting, India committed to reduction in energy emissions intensity to 35% by 2030 and increase the share of non-fossil fuel-based capacity above 40% by 2030. Political will and policy change makes a transformative change.
>
> (Policy expert, Ministry of Petroleum and Natural Gas, respondent 24)

In response to these international commitments, the government revisited national missions, revised its internal energy policy, and analysed alternative renewable sources. Modifications in the biofuel policy in 2018 focused on generating biofuel not only from the waste but also from the farming produce or any other source, helping to create a CE model. Thus, policy change is considered a key driver for CE business of Bio-CNG production not only contributing to the production of alternative energy but also achieving the national green India mission.

Demand from business

With the national agenda of the government and a change in national policy on biofuels (2018), fossil fuel suppliers have to mix biofuel with fossil fuel, and there are increasing targets of the mixture percentage (Press Information Bureau, 2022a). These changes are creating pressure on the market actors in the petroleum industry to produce more biofuel to achieve decarbonisation, this in turn is increasing demands for Bio-CNG production not only in the transportation industry but also in the industrial units.

> The environment impact is forcing drivers to change which is modifying the business demand, business models and entry of new players in the market to produce higher capacity. This is also driven by the availability of the waste raw material in both rural and urban settings […] We look forward to more Bio-CNG availability in the future.
>
> (Business Manager 1, Automobile firm, respondent 25)

The sustainability rating pressure on direct and indirect players in ecosystems such as industrial units, transport manufacturers, farming sectors, and others and combined with the development of relevant infrastructure and the introduction of policy has positively affected the demand of the clean fuel, including Bio-CNG. Additionally, carbon trading has changed the industry landscape from only production to trading of sustainability scores. Companies are not only collecting carbon credits from their clean and sustainable practices initiatives, but are also trading the carbon credits to earn money.

> The carbon trading has been strong push to companies and there is a trend of green investments. If we can reduce our carbon emissions, then we can definitely attract more investors towards our business.
>
> (Business Manager 1, Automobile firm, respondent 26)

> There are possibilities to construct Bio-CNG plants next to heavy industries that are energy intensive units. This way, we can save a lot on transportation. […] Also, Bio-CNG is a clean fuel compared to fossil fuels and has a high calorific value, which in turn improves the performance. […] This reduces environmental emissions and also provides access to low-cost fuel, which adds to profits.
>
> (Industry Expert, Chamber of Commerce, respondent 27)

The business side of sustainability, thus, is increasing demand in the industry, creating new business models, and increasing Bio-CNG production units to deal with the demand. Therefore, business demand is becoming an influential catalyst in dealing with waste management and developing CE business models.

Technology and innovation

A senior fellow (respondent 4) of the Council of Scientific and Industrial Research (CSIR) who has been dealing with the waste management research and development in the country, recognises the tectonic shift in the approach to deal with waste and create economic benefit. In the past, he dealt with many state governments that aimed at fulfilling the compliance of the GOI on environment compromising the quality of waste management units. The approach is different now, and same state governments have modified their working approach and model. Now, governments are promoting PPP models in collaboration with technology and innovation-led private companies to bring in state-of-the-art technology and a sustainable business model.

> The government is not only inviting the technologically advanced global companies to establish in India but also offering many partnership benefits under public private partnership model (PPP) including raw material supply, buy back of output, and operational support to keep the unit operational. This is new from the bureaucratic approach of government.
>
> (Entrepreneur 2, industrial unit, respondent 2)

Because of innovation and technological development, technology is available that is capable of handling large quantities of waste and producing large amounts of biofuel. The technological advancement and PPP approach has transformed the only compliance-based industry into a responsible solution-oriented business model industry, and entrepreneurs are attracted to the market to invest. This environment has motivated innovators developing locally aligned technology, which is also financially affordable in the Indian context.

> In the past, we had many small-scale biogas plants […] Such plants needed a certain mix of waste to produce biogas. Not all kinds of bio-waste could have been used in the past. Also, such bio gas plants were operated on a small scale and could not support the ambition to replace fossil fuels even in miniscule way, […]. We needed better technological capabilities and designs, and now we have them.
>
> (Operator 1, respondent 6)

> We sort and provide a mix of all kinds of biowaste to the CNG plant […] now we do not struggle to dispose of large quantities of bio-waste and we can also deal with huge legacy waste with present technology and big size units.
>
> (Municipal Officer, respondent 23)

The new technology has automated and eased the operations increasing efficiency, improving on the environmental factors, and creating smooth technology that requires less training from technology providers. Thus, technology and innovation are observed as catalysts that are not only changing the landscape of production but also addressing the environment challenges.

Profitable business model

The increase in profitable business models is playing out as a catalyst for the growth of CE in India. In the past, the waste management sector had practiced minimal compliance models to meet the government's environmental checklists. The approach did not deliver desired results such as managing environment issues or waste and hazards, or in engaging entrepreneurs to continue sustained efforts in the domain. This came from the international framework of millennium development goals (MDGs), which demanded the compliance reporting. Presently, the commitments are sustainable development in SDGs, which requires sustained business models and engagement of private sector market actors such as entrepreneurs (Rendtorff, 2019). These professionals develop stability in economic activity by their continuous effort and further contribute to achieve efficiency and better margins (Kothari et al., 2020). Innovation and technology development, financial support by government, and the initial demand creation by both state and central government invited professionals to establish business in Bio-CNG production, and it became a profitable business.

> There is sufficient financial support by government in form of debt and subsidiaries, there is good offer to the big players to invest in Bio-CNG production, and there is continuous growing demand both from the industry and individuals making it a lucrative business. Actually, return on investment (ROI) of this sector is now better than many manufacturing sectors after easing of the domain.
>
> (Entrepreneur 3, industrial unit, respondent 3)

Respondents resonate about the business models developed in partnership with municipality or agencies like fruit market, vegetable market, and farmers' communities are profitable, which was not so before policy modifications were instituted. Businesses invest money based on a business model and the continuity of the business for profit. The size of the profit is not the biggest concern, as long as it is financially stable to continue in a commoditised market.

> I do see high profit because of growing demand as the true catalyst for rapid growth in the industry. Now, we have the right balance between imported technology and equipment and locally produced equipment that makes the production a large-scale Bio-CNG production. I invested in two units as of now but plan to increase my business.
>
> (Entrepreneur 2, industrial unit, respondent 2)

> With the current level of production, our production unit will cross the break-even point in about four to five years […] We have started our production three months back. We have plans to scale up the production soon, which means we can be profitable before four years.
>
> (Entrepreneur 2, industrial unit, respondent 2)

Sustainable farming

Sustainable farming, acts as a good catalyst contributing in waste management and increasing biofuel production. Farming is an important source of raw material to the natural gas production, which is less costly due to its organic nature. In the past, India did not develop the system of farming produce or farming waste collection process that can be used for Bio-CNG production. With newer technology and business models, farming is becoming a significant source of continuous raw material supply. One respondent, who claims that this problem is echoed by many farmers, said that farmers were facing seasonal farming cycle issues, which becomes the reason of burning waste. If they did not burn waste by a time limit, then they did not get a water and fertiliser subsidy. Earlier there were no alternatives, but now farmers have other ways to manage the farm waste and to mitigate their financial burden:

> We usually reuse most of the waste generated in farming as manure or to feed the animals on the farm. […] but we do have seasonal waste from certain crops, such as paddy, cotton, and soy. This waste cannot be reused. We often burn this waste […] From the last few years, there has been a big problem, as the government has banned burning such waste. We do not have alternatives.
>
> (Farmer 1, respondent 10)

> If a Bio-CNG production plant is interested in buying our crop waste, we are happy to supply them with the waste in exchange for the right value for our efforts to transport the waste to the production site.
>
> (Farmer 3, respondent, 12)

Farm waste suddenly has a price that otherwise used to be dumped with a cost. This change has unified farmers into cooperatives and unions to negotiate the bulk deals with the businessmen and government for a long-term stable business partnership. Some seasonal waste such as straw after paddy cultivation, waste of sugarcane, and so forth cannot be used on the farms, so farmers were burning such waste post-harvest. Bio-CNG production is a solution to manage such waste. In addition, business started looking towards farming to supply continuous raw material that is not waste but organised farming for biofuel production that makes a good business model for both businesses and farmers.

The demand for farming produce and the waste as raw material for Bio-CNG production is a positive change and contributes to another national goal by, for instance, potentially doubling the farmers' income by 2025. Stakeholders of the farming and waste management or alternative fuel industry are exploring ways to increase production. Farming has become sustainable, with continued demand and in the process is profitable for farmers. The waste generated from Bio-CNG production is an excellent manure, and this supports farmers towards organic and sustainable farming.

Discussion and conclusions

This study aimed at identifying the catalysts that can facilitate the transition towards a CE for waste management in India, by utilising waste for Bio-CNG production. Qualitative thematic analysis was conducted based on data from 27 semistructured interviews. The study identified six catalysts that support the development of a CE ecosystem for waste management through Bio-CNG production. These identified catalysts are: transforming society, policy change, business demand, technology and innovation, profitable business models, and sustainable farming. This study provides valuable insights into the development of sustainable waste management practices through Bio-CNG production in India, highlighting the importance of a holistic approach to achieving a CE.

According to the findings, society is undergoing a transformation. The study highlights the importance of social sensitivity and a system-thinking approach to waste management transformation in society. The example of Indore demonstrates the significance of design, planning, and execution efforts in waste management systems, as well as the need to empower field workers. Over time, community acceptance of the changes resulted in a transition towards a CE model for waste management. The findings also bring forward how policy and regulations can lead to institutional change towards a sustainable transition to implementing CE, showcasing India's shift from protesting global environmental policies to actively shaping them.

Further, the pressure of achieving sustainability goals and carbon reduction is positively affecting the demand for clean fuels, including Bio-CNG. This change has resulted in an increase in demand for Bio-CNG in various industrial sectors. This is leading to the development of more innovative business models and the increase in more Bio-CNG production units to meet demand, thus making business demand an influential catalyst in developing CE business models. Additionally, CE in India is growing due to the increase in profitable business models, which are facilitated by government initiatives and support for entrepreneurs. The shift from minimal compliance with MDGs to SDGs has led to sustained business models and engagement of private sector market actors. Business models developed in partnership with municipalities or agencies like fruit markets and farmers' communities are now profitable. The development of efficient business operating models for medium- and large-scale waste units for Bio-CNG production is one catalyst for the growth of the CE in India.

Farming waste can be used for Bio-CNG production, which can help in waste management and increase biofuel production. Using newer technology and business models, farming waste has become a significant source of raw material supply. The waste generated from Bio-CNG production is also an excellent manure that supports farmers towards organic and sustainable farming. As a result, a two-way supply stream is creating a CE in India that meets the needs of both Bio-CNG production units and farmers. Entrepreneurs have attracted investors to the industry due to improved access to the latest and most efficient technology. In addition to automating and simplifying operations, new technology has also increased efficiency and improved the environment. This in turn enables large quantities of waste to be handled and for biofuels to be produced from that waste. Also, the findings suggests that the shift in government policies from compliance-based to solution-oriented promotes PPP models in collaboration with technology and innovation-led private players.

Past research in the CE domain notes that CE remains a concept and principle that is theoretically and practically evolving (Centobelli et al., 2020), with discussions about catalysts for CE in the recent literature. In their recent literature review, Sarja et al. (2021) identified different types of catalysts for an organisation to transit into a CE. These catalysts are very business-centric and keeps organisational-level transition to the CE in the focus. But we still do not know how these catalysts evolve under various context and which catalysts govern or motivate different stakeholders to get involved in the CE of a product or a production unit. Hence, the CE can be ambiguous in many contexts and stages of its implementation (Geissdoerfer et al., 2017; Kalmykova et al., 2018). Also, except for a few studies, it is difficult to find any literature that discusses the basic 'need' of the context as a catalyst for adoption of CE (e.g., Korhonen et al., 2018; Niinimäki, 2017). Based on the findings, we argue that stakeholders' fundamental needs serve as catalysts and their alignment to engage for implementing a CE.

In our study, the government's needs for economic growth, self-reliance, and achieving global targets for the mitigation of climate change can be achieved through policy change that promotes CE. For example, the government could incentivise businesses to adopt circular practices, such as reducing waste and reusing resources, which could lead to increased economic growth and self-reliance while also reducing greenhouse gas emissions, thus promoting CE. The municipality's need for efficient and clean waste management can also be met through a CE approach. By implementing a closed-loop system where waste is used as a resource for producing Bio-CNG, the municipality can reduce the amount of waste that goes to landfills and use it instead to produce a renewable energy source. This implementation could also create opportunities for municipalities to become important suppliers for Bio-CNG production, thus creating additional economic benefits for both the production unit for Bio-CNG and the municipality authority.

Similarly, the business sector's needs for cleaner and cheaper fuel and reduction in emissions can also be addressed through a CE approach. By buying Bio-CNG as a fuel, businesses can reduce their carbon footprint while also benefitting from a more affordable and sustainable energy source. Further, individual members in the society needs for a clean environment, affordable fuel, and maintaining and enhancing life choices can be met through their participation in a CE. By becoming responsible partners for waste management by partnering with municipalities, individuals can contribute to reducing waste and minimising the impact of their activities on the environment. In addition, Bio-CNG is a cheaper and cleaner fuel and could help to enhance the individuals in a society's life choices. Finally, the farmers' requirements of better seasonal waste management, extra income, and organic manure can also be met through participation in the CE. It is the combined needs of the stakeholders that is catalysing the creation of a healthy ecosystem for Bio-CNG production through waste management. Table 6.3 summarises the identified stakeholders' needs.

In India, the government and its policies continuously support the ecosystem of the stakeholders to adopt the CE practices; this is seen as a central enabler to CE. Other stakeholders will participate in the ecosystem to produce Bio-CNG through waste management, thus fulfilling and supporting a CE. The findings of our research show that the primary catalyst for any ecosystem to transition to a CE is the basic need for stakeholder transformation; when the needs of different stakeholders are synchronised, the CE transition is possible. If the essential requirements of the stakeholders are not aligned, then the actions of each stakeholder are also not aligned and even

Table 6.3 The need analysis of the key stakeholders

Stakeholders	*Needs*	*Actions*
Government	1 Economic growth 2 Self-reliance 3 Achieving global targets for the mitigation of climate change	Policy change
Municipality	1 Efficient and clean management of large-scale waste	Willingness to become an important supplier for Bio-CNG production
Business	1 Cleaner and cheaper fuel 2 Reduction in emissions	Willingness to buy Bio-CNG as a fuel
Individuals	1 Clean environment 2 Cheap fuel 3 Maintain and enhance life choices	Willingness be a responsible partner for waste management with the municipalities
Farmers	1 Better management of seasonal waste 2 Extra income 3 Organic manure	Willingness to become an essential supplier for Bio-CNG production

in the case of identified incremental improvements, finding an easy path to CE transition through continuous development may not be easy. Overall, the needs listed in Table 6.3 highlight the importance of reducing waste, increasing resource efficiency, and creating sustainable economic opportunities, all of which are key elements of a CE. By addressing these needs and promoting circular practices, stakeholders can contribute to creating a more sustainable and resilient future for all.

Future research and limitations

The purpose of this study was to identify the catalysts of transition of the biowaste industry to a CE in India. Since the segment is in a nascent stage, we employed qualitative methods and applied thematic content analysis to research the current field. There are limitations in the process such as it is based on open-ended inquiry about a phenomenon of interest, the CE.

In the context of India, there are several potential areas for future research to encourage the transition to a CE. First, research could focus on the role of policy updates in promoting circular practices among businesses, individuals, and other stakeholders. This could involve exploring the potential for new policies and regulatory frameworks that could facilitate the transition to a CE especially in the supply chain context. Second, there is a need to explore the social, technical, and economic feasibility of regime transition waste-to-energy technologies on a larger scale, especially in different regions of India, which are diverse both geographically and culturally. Finally, future studies could focus on the potential development of supply chains for the easy mobility of waste to production units and the easy mobility of Bio-CNG to potential users. This could involve examining the logistics of transporting waste and Bio-CNG across different regions of India, as well as identifying potential solutions to overcome barriers in the supply chain. By addressing these research gaps, policymakers and practitioners can gain a better understanding of the potential benefits and challenges of CE in India and identify strategies for promoting a more sustainable and resilient future.

The formation of CE in the biowaste context is in the nascent stage (Chhimwal et al., 2022). As the domain evolves, dynamics of the drivers and catalysts will change, which will be of interest to researchers, as this subject and research outcomes will modify many fundamental questions of interplay of groups and systems (Ghisellini et al., 2016). The interaction of the stakeholders plays a key role in guiding firms to adopt CE practices (Lahane & Kant, 2022). Through the passage of the industry life cycle, stakeholders' needs and catalysts will introduce new business models and cluster effects to enhance the effectiveness of CE in the long run (Wielopolski & Bulthuis, 2022). The development of the ecosystem and the scalability of market will depend on stakeholder acceptance (Esa et al., 2017). In literature, it has been found that a variety of stakeholder groups influence the adoption of CE practices in the development of ecosystems (Jakhar et al., 2018), however researchers still need to identify the strategic fit of the selected stakeholders in development of the CE's ecosystem. The shift towards manufacturing of Bio-CNG through waste management is a substantial paradigm shift in India, and involves many stakeholders that directly or indirectly contribute to the formation of CE. With the maturity of this industry in the future, we will have to understand how stakeholder needs evolve based on this and how catalysts change with the evolution.

Educational content

- The chapter introduces how India is leading the conversation about sustainability through providing a glimpse of achievements in waste management initiatives. Further, it introduces the Indian conversation about sustainability to a global audience. This chapter addresses catalysts in developing CE ecosystems and how Indore, a city in central India, has managed to shift to a CE model and win an award for the cleanest city.
- This chapter promotes understanding the performance of the government in dealing with complex sustainability issues in the given context of population, societal setting, institutional support, entrepreneurial spirit, and growth.

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