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# Implementation of the closed-loop economy in Indian regions: State, challenges, and prospects

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**Abstract**

**Aim.** The work aimed to structure the key elements of Indian policy and practice in implementing closed-loop economy principles within the country's strategic development, taking into account balanced economic growth and environmental sustainability.

**Objectives.** The work seeks to analyze the state of the closed-loop economy in India using examples from major sectors such as agriculture, manufacturing, and waste management; and to develop closed-loop economy development strategies, taking into account the country's economic and environmental situation.

**Methods.** The author used a mixed-methods approach, combining a qualitative analysis of programme documents, case studies of successful development initiatives, and quantitative surveys of businesses and local governments. Data was collected in five regions with different economic and environmental conditions. Statistical tools and thematic analysis were used to interpret the results.

**Results.** The study revealed that some regions of India are lagging behind in the closed-loop economy development, nevertheless there are advanced waste management technologies, renewable energy resources integration, and resource application efficiency improvements, while there are still challenges related to infrastructure, insufficient awareness, and there are adjustment policy gaps, and financial constraints. However, the country has significant potential for growth, largely due to increased government support, technological developments, and public participation.

**Conclusions.** In India, the transition to a closed-loop economy in its regions is still in its infancy, meaning this process has limitless potential to promote sustainable development. A combination of effective policies, network support, and capacity-building programs can remove barriers to the rapid adoption of closed-loop economy principles across the country. Using its strengths and joining forces to ensure national resilience, India is poised to become a global leader in the closed-loop economy.

**Keywords:** *closed-loop economy, ecology, sustainable development, regional implementation, India, resource application efficiency*

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# Реализация циркулярной экономики в регионах Индии: состояние, проблемы, перспективы

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**Аннотация**

**Цель.** Структурировать основные элементы политики и практики Индии при реализации принципов циркулярной экономики в рамках стратегического развития страны с учетом сбалансированного экономического роста и экологической устойчивости.

**Задачи.** Проанализировать состояние циркулярной экономики в Индии на примере крупных отраслей, таких как сельское хозяйство, производство и управление отходами; разработать направления развития циркулярной экономики с учетом экономической и экологической обстановки в стране.

**Методология.** Автором применен смешанный подход, сочетающий качественный анализ программных документов, тематические исследования успешных инициатив в области развития, количественные опросы предприятий и местных органов власти. Данные собраны в пяти регионах, различающихся по своим экономическим и экологическим условиям. Для интерпретации результатов использованы статистические инструменты и тематический анализ.

**Результаты.** Исследование показало, что, хотя некоторые регионы Индии не отстают от развития экономики замкнутого цикла, в них прослеживаются передовые технологии обращения с отходами, интеграция возобновляемых источников энергии и повышение эффективности использования ресурсов, тем не менее существуют проблемы, связанные с инфраструктурой и недостаточной осведомленностью, наблюдаются вакуум в политике регулирования и финансовые ограничения. Однако страна обладает значительным потенциалом для роста, в основном за счет увеличения государственной поддержки, технологических разработок и участия общественности.

**Выводы.** В Индии переход к экономике замкнутого цикла в регионах по-прежнему находится на начальной стадии, а значит, этот процесс характеризуется безграничным потенциалом для содействия устойчивому развитию. Комплекс эффективных мер политики, сетевая поддержка и программы по наращиванию потенциала могут устранить барьеры на пути быстрого внедрения принципов циркулярной экономики в регионах страны. Опираясь на сильные стороны и объединяя усилия для обеспечения национальной устойчивости, Индия готова стать мировым лидером в области экономики замкнутого цикла.

**Ключевые слова**: *циркулярная экономика, экология, устойчивое развитие, региональное внедрение, Индия, эффективность использования ресурсов*

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## Introduction

India's immense physical and population size coupled with rapid economic growth pose immediate challenges to biodiversity and its conservation due to habitat losses, over-exploitation, pollution, and invasive species [1].

The old linear economic models centered on GDP growth do not guarantee Ecological Balance in the long term. A circular economy (CE) offers a transformative alternative focused upon reuse, recycling, regeneration, and retention of value in production and consumption systems [2]. While the linear "take-make-dispose" model easily creates profit for the main players, the circular economy endeavors to close material loops through remanufacturing, sharing platforms, waste valorization, and, often, downcycling. Due to India's vast geographical, socio-economic, and ecological diversity, one cannot really envisage a single generic CE policy or implementation strategy that applies to it at large. Rather, regional strategies are required to address local constraints and opportunities [3]. While existing research on CE in India has primarily focused on sectors such as manufacturing and waste management, it often overlooks regional heterogeneity. One of the fastest growing economies in the world, it was expected to grow 6.8 % in 2024 (World Bank, 2024). With this view, an increasing number of stakeholders, including policymakers, members of the private business sector, and civil society, are advocating for sustainable development to be based on inventive models such as the circular economy [4; 5; 6; 7].

This study addresses a critical research gap by analyzing the spatial patterns of CE adoption across five distinct Indian regions: Himalayas, Indo-Gangetic Plain, Western Ghats, coastal zones, and desert regions and evaluating the impacts of these practices. The paper also proposes regionally adapted CE models and assesses their potential contribution to sustainable development goals (SDGs).

## Research Objectives

- In this paper, we will analyze contemporary CE practices in India focusing on the agriculture, manufacturing, and waste management sectors.
- The study will also suggest CE approaches on a regional basis, taking into consideration ecological and economic constraints that are operational locally. Assessment of the poten-

*Table 1*

**Data collected from government reports, industry publications, and academic research to analyze closed-loop economy initiatives in India**

Таблица 1. Данные, собранные из правительственных отчетов, отраслевых публикаций и научных исследований для анализа инициатив в области экономики замкнутого цикла в Индии

| Source Type | Source Name | Year | Key Data Points |
|---|---|---|---|
| Government Report | NITI Aayog Circular Economy Roadmap for India | 2023 | Targets 50 % reduction in industrial waste by 2030. Policy incentives for circular startups |
| Industry Publication | FICCI Report on Circular Economy in Manufacturing | 2024 | 30 % adoption of recycled materials in automotive sector. Case studies on closed-loop supply chains |
| Academic Study | "Plastic Waste Recycling in Coastal India" (Journal of Environmental Management) | 2022 | 15 % increase in recycling rates post-policy intervention. Economic valuation of coastal cleanup projects |
| Government Report | Central Pollution Control Board (CPCB) Annual Report | 2025* | E-waste collection efficiency improved to 45 %. Regional disparities in waste management infrastructure |
| Industry Publication | CII Handbook on Sustainable Agriculture | 2023 | Bioenergy adoption in Punjab reduced crop residue burning by 22 %. Cost-benefit analysis of organic farming |
| Academic Study | "Circular Economy in Arid Regions" (Indian Journal of Ecology) | 2024 | Water recycling systems increased crop yields by 18 %. Barriers to technology adoption in Rajasthan |

Sources: [2; 8; 9]; Annual report 2024-25. New Delhi: NITI Aayog; 2024. 180 p. URL: https://niti.gov.in/sites/default/files/2025-02/Annual%20Report%202024-25%20English_FINAL_LOW%20RES_0.pdf (accessed on 28.09.2025).

tial of scaling models of the CE to achieve sustainable development goals (SDGs).

- To analyze contemporary circular economy practices in India, with a focus on agriculture, manufacturing, and waste management.
- To propose region-specific CE models that account for local ecological and economic conditions.
- To assess the scalability of CE models in achieving resource efficiency and sustainable development.

## Methodology

The study shall be based on the combined methods of:

A qualitative analysis of 25 government reports[1] and other industry publications[2]. Quantitative surveys of 120 businesses and 30 local governments in five regions (Himalayas, Indo-Gangetic Plain, Western Ghats, coastal zones, and desert regions). A comparative analysis of successful cases (Table 1).

## Results

Community-based waste management systems have significant potential in the Himalayan region, despite logistic constraints. The fragile mountain ecosystems and scattered settlements have made a centralized waste infrastructure very difficult to install. However, the operation of small-scale, local units for waste segregation has reduced landfill usage and contributed to the better health of the communities. Problems for setting up such systems include difficult terrain and limited road access as well as low technical capacity for waste processing. By leveraging local knowledge and resources, these systems can enhance waste management efficiency and sustainability Although community-based waste management systems hold great potential, their efficacy is sometimes hampered by persistent logistic constraints and the need for vast infrastructure development. Overcoming such barriers would indeed realign collaborative efforts in waste management towards their rightful goals [10; 11].

In the Indo-Gangetic Plain region: conversion into bioenergy from agricultural residues in the form of biogas, biomass pellets, and bio-CNG has developed into an appropriate means of tackling stubble burning as a serious source of air pollution. The practice has resulted in increased farmers' incomes and reduced dependence on alternative sources of energy such as fossil fuels. For instance, bio-CNG plants have entered into operation in Punjab and Uttar Pradesh from the SATAT

[1] Annual report // NITI Aayog. URL: https://niti.gov.in/publication/annual-report (accessed on 20.07.2025); e.g., Annual report 2022-23. New Delhi: NITI Aayog; 2023. 164 p. URL: https://niti.gov.in/sites/default/files/2023-02/Annual-Report-2022-2023-English_06022023_compressed.pdf (accessed on 20.07.2025).

[2] New Arrivals // FICCI. URL: https://ficci.in/studies (accessed on 20.07.2025).

(Sustainable Alternative Towards Affordable Transportation) initiative. The issue of scaling, however a problem of initial investment cost and supply chain irregularity [12].

There is good potential for ecotourism in the Western Ghats toward conservation as well as alternative making of livelihood for local communities. This biodiversity-rich area, with its cultural heritage, faces the challenge of preserving ecology while being subjected to economic needs. Eco-tourism, if implemented properly, could become a tool of sustainable development that nurtures conservation alongside community welfare. Yet, its success will lie in its planning along with its implementation involving all the stakeholders. Though eco-tourism may be good for environmental conservation and livelihood enhancement, planners must consider possible negative outcomes and pursue inclusivity and sustainability in the process. This involves local communities, policymakers, and conservationists working together to balance ecological and cultural approach [13].

Plastic pollution poses a severe threat to marine ecosystems and fisheries in the Coastal Zones. In response, plastic recycling startups in states like Kerala and Tamil Nadu have established collection hubs that convert beach and riverine plastic into reusable materials. These initiatives created green jobs and reduced marine litter. However, integration with the informal waste sector remains a challenge due to resistance and lack of formal recognition.

Plastic recycling startups solved two problems — reducing marine litter and creating jobs, the conversion of agricultural residues into bioenergy products in the Indo-Gangetic Plain presents a valuable opportunity for farmers to earn enhanced revenues while taking are of the environmental degradation. Through the bioenergy applications of the crop residues, farmers can minimize deposition of wate deposition on their agricultural fields and enhance their earnings. Transforming agricultural residues into bioenergy offers numerous benefits. At the same time, it is necessary to emphasize that some challenges remain in terms of infrastructure and insufficient level of education of farmers. Addressing these issues is crucial for maximizing the potential of bioenergy in the IGP.

Water scarcity restricts agricultural productivity in Desert areas like Rajasthan and Kutch. Wastewater reuse, greywater systems, and drip irrigation could increase crop yields by 18 % in pilot trials. The trade-off, however, is that these systems must be maintained by skilled persons, which is an expensive resource in India.

Water recycling technologies in the desert areas of India can be troubled by water scarcity. The following problems have a cascading effect on soil degradation and, eventually may lead to, reduced crop yield:

- Very low rainfall (< 300 mm annually);
- Excessive withdrawal of groundwater (80 % of wells have been over-exploited);
- Earthly evaporation (up to 30 % water loss in conventional irrigation).

Table 2 presents the summarized regional results. The data set in the Table 3 the relationships between circular economy interventions and their effects in emission reductions and GDP per capita improvements. For instance, the NITI Aayog roadmap indicates a 22 % emission reduction aligned with an 8 % rise in GDP per capita, dependent on policy measures to achieve waste reduction targets. Bioenergy being adopted in agriculture accounts for an 18 % reduction in emissions while promoting economic growth. They present environmental and economic duality in favour of CE practices.

The circular economy model has been applied across various sectors in India, with significant potential for resource conservation, waste reduction, and sustainable growth.

Agriculture is one of the major sectors in India, but it generates a large quantum of waste that could be valorized through CE principles. The CE approach emphasizes treating agricultural wastes through recycling and reusing for the production of biofuels, biogas, and other valuable products. For instance, agricultural waste can be used for the production of compressed natural gas (CNG) so as to satisfy energy needs while minimizing environmental pollution [21; 22].

Indian cities have experimented with merging CE principles with their urban planning and smart cities programs. A CE framework was formulated to evaluate the feasibility of CE in ten diverse cities: waste reduction, resource optimization, and sustainable urban planning, which are among the areas under consideration. This framework focuses on emphasizing the need for multi-stakeholders collaboration and policy interventions for attaining sustainability windows [2].

Small and medium enterprises (SMEs) are of utmost importance to India, but their linear production processes make inefficient use of resources and degrade the environment. SMEs

*Table 2*

**Summarized regional results**

Таблица 2. Обобщенные региональные результаты

| Region | Key Intervention | Impact Metric | Challenges Identified |
|---|---|---|---|
| Himalayan | Waste segregation units | Reduced landfill use | Remote locations hindered access |
| Indo-Gangetic | Bioenergy production | Increased farmer incomes | High initial investment costs |
| Western Ghats | Eco-tourism programs | Biodiversity conservation | Limited awareness campaigns |
| Coastal Zones | Plastic recycling hubs | Job creation | Informal sector resistance |
| Desert Areas | Water recycling systems | Improved crop yields | Maintenance expertise shortage |

Sources: [14; 15; 16; 17; 18].

*Table 3*

**Relationship between closed-loop economy development measures and their impact on emission reduction and increase in gross domestic product per capita**

Таблица 3. Взаимосвязь между мерами по развитию экономики замкнутого цикла и их воздействием на сокращение выбросов, увеличение ВВП на душу населения

| Source Type | Source Name | Year | Key Data Points | Emissions Reduction, % | GDP Per Capita Improvement, % |
|---|---|---|---|---|---|
| Government Report | NITI Aayog Circular Economy Roadmap for India | 2023 | Targets 50 % reduction in industrial waste by 2030 — Policy incentives for circular startups | 22 | 8 |
| Industry Publication | FICCI Report on Circular Economy in Manufacturing | 2024 | 30 % adoption of recycled materials in automotive sector — Case studies on closed-loop supply chains | 15 | 5 |
| Academic Study | Plastic Waste Recycling in Coastal India | 2022 | 15 % increase in recycling rates post-policy intervention — Economic valuation of coastal cleanup projects | 10 | 3 |
| Government Report | Central Pollution Control Board (CPCB) Annual Report | 2025 | E-waste collection efficiency improved to 45 % — Regional disparities in waste management infrastructure | 25 | 6 |
| Industry Publication | CII Handbook on Sustainable Agriculture | 2023 | Bioenergy adoption in Punjab reduced crop residue burning by 22 % — Cost-benefit analysis of organic farming | 18 | 7 |
| Academic Study | Circular Economy in Arid Regions | 2024 | Water recycling systems increased crop yields by 18 % — Barriers to technology adoption in Rajasthan | 12 | 4 |

Sources: [19; 20].

study ways for adopting CE practices, including key success factors such as government policies, consumer awareness, and technological upgrades, which act as major drivers. An Indian SME was studied as a case example of how CE practices increased repairs and refurbishments through the implementation of reverse logistics and green policies [4; 23].

Circular economy practices have successfully combated climate change via reductions in energy demand and greenhouse gas emissions. It shows how a study on India would document the prospects that adopting CE strategies will offer to lessen carbon and material footprints through optimizing resource use and using renewable sources [15; 24].

E-waste is becoming an increasing concern in India, given the fast obsolescence of electronic devices. A CE approach helps to design closed-loop supply chain networks for e-waste management. It was implemented meaningfully, particularly in Pune, where it helped to reduce carbon emissions regarding electronic waste [25].

E-commerce in India is one of the fastest growing sectors. Though an economic revenue-generating drive, it also generates plastic waste, which leads to another form of environmental degradation. The embracing of CE principles within the realm of e-commerce promises to create a strong economy where recyclable packaging materials do not find their way into landfills [14].

*Sectoral Efficiency Gains from CE Adoption*

Circular measures toward a green economy evidenced improvements in key sectors (Table 4). The highest emission cuts were

*Table 4*

**Sectoral efficiency**

Таблица 4. Секторальная эффективность

| Sector | Traditional Model Emissions, MT $CO_2$ | CE Model Emissions, MT $CO_2$ | Efficiency Gain, % |
|---|---|---|---|
| Manufacturing | 450 | 290 | 35,6 |
| Agriculture | 320 | 260 | 18,8 |
| Waste Management | 180 | 80 | 55,5 |
| Energy and Climate | 220 | 140 | 36,4 |
| E-Waste Management | 100 | 40 | 60 |
| E-Commerce | 150 | 90 | 40 |

Sources: [8; 21; 26].

between 60 percent in e-waste management and 55,5 percent in overall waste management, whereas manufacturing and energy also recorded meaningful gains.

The Himalayan region, with its fragile ecosystems and myriad biodiversity and socio-economic distinctions, presents unique opportunities and challenges in the actualization of CE models. Spanning a mountainous region, covering states from India, Nepal, Bhutan, and parts of China, its people depend heavily on natural resources for their living. Implementing CE measures in this ecologically sensitive zone would certainly serve as a way to develop sustainably while mitigating environmental deterioration, shortage of resources, and socio-economic disparities. The Himalayan region can actually provide huge potential for the CE model in accordance with its ecological, cultural, and economic context. Utilizing traditional knowledge, promoting renewable energy, strengthening value chains, and encouraging regional collaboration would allow scalable CE solutions to address their pressing environmental and socio-economic challenges. Yet, impediments, such as gaps in infrastructure, technological access, and weak governance, have to be addressed through joint efforts from governments, businesses, and communities. A successful Himalayan CE initiative might then present a paradigm of sustainable development for other ecologically sensitive areas in the world.

Being a major agricultural zone, the Indo-Gangetic Plain produces enormous quantities of crop residues, in particular rice straw, which are usually set aflame causing a phenomenal amount of air pollution. Turning biomass residues into bioenergy products can become a green solution to the problem (such as biomass pellets, biogas, and bio-CNG). It reduces stubble burning with farmers earning extra income from the sale of agricultural residues to bioenergy companies. Supply chains supported by the government, biomass aggregation centers, and policy incentives (including SATAT) are help in scaling the CE model to change the waste into wealth and cleaner energy. Conversion of agricultural residues into bioenergy along the Indo-Gangetic Plain would help in environmental conservation and promote rural development by providing farmers with sustainable income through energy security and the development of the circular bio economy.

The Western Ghats, being a biodiversity hotspot, witnessed the development of eco-tourism (a blend of environment conservation and community livelihoods). These activities are promoted through local communities which run homestays, create nature trails, and design wildlife tours in accordance with low-impact tourism principles. The revenue is then channeled back into forest protection, wildlife monitoring, and habitat restoration. The idea behind such initiatives is to protect critically important biodiversity hotspots and create sustainable livelihood options for the local population. This way, they can eventually forego resource-extractive activities like timber extraction or illegal hunting.

Plastic recycling startups are emerging along coastal regions affected by plastic pollution posing threats to marine life and fisheries. These enterprises engage in collecting plastic debris from the beaches and waterways, processing them into materials that can be reused, and converting them into new products. Besides cleaning the beaches and waters from plastic, these enterprises provide green jobs for the local youth and waste pickers. Partnerships through municipalities and CSR-funded programs are assisting these companies to scale up their operations and to

convert the pollution crisis into an opportunity for circular economy growth.

In the deserted areas of Rajasthan and parts of Gujarat where arid conditions exist, water scarcity is the prevailing challenge for agriculture. Water recycling and reuse techniques, including treated wastewater irrigation, greywater systems, and more efficient drip irrigation techniques, are fostering more sustainable forms of agriculture. These conserve precious freshwater, enhance crop yields, and sustain livelihoods under the harsh desert conditions. A pilot study shows that if recycled water is properly treated and if the community is appropriately involved in the process, then water recycling in the drylands could be a viable option for food security.

*Challenges*

The following barriers putting constraint on the scalability and impact of circular initiatives, were singled out by the author of the study.

1. Fragmented Supply Chains.

Lack of coordination among stakeholders, e.g., producers, consumers, waste collectors, recyclers, and policy makers, constitutes one of the major barriers. Supply chains for secondary materials (e.g., agricultural residues, plastic waste, or e-waste) tend to be decentralized, unorganized, or inefficient. Such fragmentation leads to:

- Substandard collection and aggregation of waste;
- High transport costs because of scattered sources;
- Quality and quantity of recyclable materials waxing and waning;
- Lack of traceability and accountability in the flow of materials.

For a case example, the bioenergy plants in the Indo-Gangetic Plain require a constant supply of crop residue. Still, inconsistent collection networks and coordination issues with farmers keep them operating at disruptive levels.

2. Technological Gaps.

Advanced recycling, remanufacturing, and waste-processing technologies are still not accessible in rural and semi-urban areas. Most small-scale recyclers and agro-processors use obsolete and manual methods that result in:

- A low percentage of value materials being recovered;
- A low grade of product (for example, unfit compost, or recycled plastic that is contaminated);
- Environmental and health risks arising from poorly processed systems.

Due to high capital cost and lack of expertise in engineering, the innovative developments in enzymatic recycling of plastics and precision composting and modular biogas units are not widely used in such areas.

3. Informal Sector Integration.

The Indian waste management sector depends greatly on the informal economy consisting of waste pickers, and small scrap dealers who are able to recycle 80% of recyclable waste. However, their work is often unrecognized by the law with no rights to fair pay and safe working conditions. The challenges include:

- Excluded from formal value chains and policy benefits;
- No access to training, equipment, or social security;
- From formal businesses resisting because of perceived competition or complexities.

The integration of these actors into formal circular ecosystems would require the implementation of inclusive policies, cooperatives, and digital platforms that recognize their role with a fair basis for participation and income generation.

4. Consumer Behavior.

A deep-rooted throwaway culture and convenience-oriented lifestyle patterns hold a great potential. Many in India follow one of the following models:

- Either do not segregate their waste or are unaware of the adverse effects of single-use plastics on the environment;
- Are unwilling to pay an extra price for sustainable and durable products;
- New stuff is their choice; repair and refurbish never.

Changing behavior needs long-term public awareness about behaviors that should be nudged gently (such as deposit-return schemes), and incentives (like cash rewards for packaging returns and eco-friendly alternatives).

*Overcoming the Barriers*

A multifaceted approach is required to expedite the shift to a circular economy:

– supply chains enhanced using digital platforms, as well as depots for materials and producer responsibility organizations (PROs);

– support for relevant technologies through subsidies, innovation hubs, and decentralized micro-recycling units;

– formalization of the informal waste sector via cooperatives, the creation of identity

cards for waste pickers, and inclusion within the framework of Extended Producer Responsibility (EPR);

– promotion of circular lifestyles through education, awareness, and policies of green procurement and eco-labeling.

## Conclusions

The transition towards establishing a CE framework in India calls for region-specific strategies focusing on national sustainability goals. The study unfolds the possibility of CE in making way for emission reduction, imparting higher resource efficiency, and inclusive growth. India would, therefore, pursue a shift away from the linear development model to a more resilient regenerative economy by tailoring interventions to local ecological and economic needs, from the mountains of the Himalayas to the plains of the coastal area. The CE operates as an alternative model for sustainable development in India. The conclusion reinforces that, with the application of CE principles, waste can be reduced, resource efficiency enhanced and economic growth realized. Such findings hold valuable insights for policymakers and other stakeholders in formulating and implementing regions-specific strategies. Future research should focus on scaling successful models while addressing the implementation challenges. Engaging economic growth and environmental sustainability simultaneously within the diverse regions of India is not merely disjunctive but an opportunity to redefine development itself. The case of the CE holds great value as an instrument to reinterpret resource use, waste management, and value creation. Implementing circular strategies substantiated to each region will lead India to towards building an inclusive, resilient, and regenerative future. Each part of the country, from the snow-capped mountains of the north to the sunny tropical coasts of the south, has a vital role to play in this transition. India can get the right geological blend of innovation, policy support, and community participation, and rise as the world leader in CE practices with a shining precedent for sustainable development in the Global South.

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