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From sugar production to sustainable energy production: exploring scenarios and policy implications for bioenergy in the sugar bowl of India

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ABSTRACT

In the post climate change era energy conservation and alternative sustainable energy pathways like bioenergy have drawn global attention. Amongst the various sector sugar industry is considered as most promising sector for biofuel production from renewable resources. Indian sugar industry is the second largest producer of sugar in the world after Brazil. Electricity production through cogeneration in sugar mills in India is an important avenue for supplying low-cost, non-conventional power to mitigate sustainable energy challenges. This study aims to lend insight into the future scenarios of sustainable bioenergy through bagasse cogeneration by sugar factories, principally to assist sustainable energy policy making process in India. The study primarily relies on futures studies methodology particularly, mini Delphi, PESTEL, System Axis and Scenario construction. The study concludes four distinctive alternative scenarios and policy implications for bagasse based bioenergy production in the India's one of the largest sugar zones viz: Solapur district Maharashtra State. From policy point of view this study is a step forward to assist to prepare plan and course of action considering sustainability as a central relevance in bioenergy policy making.

Key words : *Sustainable energy, Bagasse cogeneration, Sugar factory, Scenarios, India.*

Introduction

The aspiration for universal access to modern energy and the use of renewable energy technologies (RETs) as a means of delivering low carbon solutions are driven by several local and global factors, including climate change, Paris Agreement, population increase and sustainable future energy security. India is the fourth largest greenhouse gas emitter globally. Therefore, it has become a crucial agenda for the Indian Government to reduce such emission for sustainable energy security. It is in this context, Indian Government has taken keen initiatives to achieve the renewable energy target of 175 GW by the year 2022. This includes 60 GW from wind power, 100 GW from solar power, 10 GW from biomass power and 5 GW from small hydro power (MNRE, 2013). India is emerging as a responsible actor towards 'low carbon civilization' through 'clean energy movement'. India's clean energy policy environment harnessing Renewable Energy (RE) from all available sources including, Bio-fuels (Bagasse cogeneration). Cogeneration of bagasse is one of the most potential RE sources that have already been demonstrated in many sugarcane producing countries such as Brazil, Cuba, Mauritius and South Africa. However, this sector is relatively under researched.

Bagasse cogeneration: A Sustainable Approach

Electricity production through cogeneration in sugar mills in India is an important avenue for supplying low-cost, non-conventional power to mitigate sustainable energy challenges. Indian sugar industry is the second largest producer of sugar in the world after Brazil. In India, sugar industry is the second largest industry after textiles. The country is the second largest sugar producer in the world (accounting 13% of the world's sugar production). As sugar production is high in country bagasse which is leftover of sugarcane is available abundantly which is further used to generate electricity by cogeneration process.

What is Bagasse cogeneration?

Bagasse is the fibrous matter that remains after sugarcane stalks are crushed to extract their juice and is a by product generated in the process of manufacture of sugar. The bagasse produced in a sugar factory is however used for generation of steam which in turn is used as a fuel source and the surplus generation is exported to the power grids of state governments. In India, interest in high-efficiency bagasse based cogeneration started in the 1980s when electricity supply started falling short of demand. It is estimated that bagasse-cogeneration has potential to generate 5000 MW (31.12.2016). Apart from this additional 7000 MW of power could be generated through bagasse based cogeneration if 550 sugar mills will adopt technical and economical optimal levels in process (Patel, 2017). Thus, considering the policy significance and future potential of this sector a study has been conducted with futures perspective in the light of the following methodological framework.

Materials and Methods

The study area

Solapur is one of the swiftly growing agro-industrial districts in Maharashtra state of India. The district is situated on the south east border of Maharashtra state and sited exclusively in the tributaries of Bhima and Seena rivers. Sugarcane is one of the focal staple crops in the district. The data during 2005-06 and 2011-12 shows over 160 % growth in sugar cultivation (Sandrip, 2013). Of the total 173 sugar factories in Maharashtra state Solapur District alone comprise highest 47 sugar factories. Thus, the district has the largest number of sugar factories in the country and exhibits huge potential for bio-energy production from baggase based cogeneration plants installed in the sugar factories. Therefore, present study has purposively been conducted in Solapur district as an ideal representative case.

Samples

Selecting sample respondents for researching on trans-disciplinary areas like bioenergy is not just a head count. It goes beyond and explores a group of classified respondents having intimate knowledge of a problem under investigation. It is in this context 40 samples have been selected purposively from four specific key areas unswervingly associated to the present study (Table 1).

Methods

As far as methods are concerned four specific methods have been applied **i)** Mini Delphi ii) PESTEL iii) System Axis/Grid and iv) Scenario construction. Mini Delphi is a strategic forecasting method that engage planned interface amongst the focused group of experts from diverse fields with at least two rounds interfaces. According to Wendell Bel(1997) Delphi researchers aim to predict and explore alternative future possibilities, their probabilities of occurrence, and their desirability by tapping into the expertise of respondents. Altogether 40 experts were gathered together to discuss on the intended research questions and to bring their own argued future views into the discussion during June-August, 2018. PESTEL is a holistic framework stands for Political, Economical, Social, Technological, Environmental and Legal aspects applied to analyse macro level subtle intricacies having profound impact on the subject under investigation. System axis/grid is one of the futures studies focal methods intending to explore key influencing factors their inner connections and governing factors on each other. It sets stage for drawing alternative scenarios. Scenario construction is a unique method concerning how the future of specific area/issue/policy might develop. It helps policy makers to postulate possible future and to establish new ways of analysing and planning for the preferable future to avoid future risks.

Research Questions

General research question

What are the intricate consequences, critical pathways and future potential influencing factors that

Table 1. Sample framework

Sr. No.	Key Areas	Sample size
1	Representative from Sugar factories	10
2	Representative from academia	10
3	Representative from state cooperative sugar department	10
4	Representative from sugar consultancies/research groups	10
	Total sample size	***40***

offer alternative scenarios for the prospects of Bagasse Cogeneration Sector (BCS) @ 2030?

Specific Research Questions

i) What are the favourable, neutral and unfavourable factors that explore critical pathways for the future prospects of (BCS)?
ii) What are the key influencing factors their interconnections and influence on each other for drawing alternative scenarios for (BCS)?

Results and Discussion

This section analyses the core research questions of the study and their corresponding results and discussions. The first research question was operationalized through PESTEL method. Through PESTEL analysis the study identified four intricate factors i) factors favourable to the BCS ii) factors are of neutral impact on the BCS iii)factors are of unfavourable impact on the BCS and iv)overall impact and general conclusion(Table 2). These factors helped to understand "big picture" and 'forces of contemporary/future relevance' involved in (BCS) sector at Solapur district and having relevance at the macro level these are as follows.

As seen in Table 2 the PESTEL analysis reflects overall impact into four set factors, overall the Political sphere of BCS confirm favourable impact due to conducive policy/political environment provided by Modi government towards renewable energy sector since its inception. At national level the Modi government has created a positive environment through enacting favourable policies, plans and programs (e.g Energy for all) and engaged in agreements (Paris Treaty) related to sustainable development at international level to make India a clean and zero carbon country. However, there are contradictions at the national and local level political leadership with regard to RE in general and BCS in particular. Issues like tensions between sugar cane growing farmers and state and sugar factories in terms of minimum support price for sugar cane and energy produced by bagasse cogeneration often causes conflicts. Similarly, the Indian sugar industry is under high political influence with deep political economy. Mainstreaming such issues at local level needs to be resolved for future sustainability. The economic factor show overall neutral impact due to few major reasons such as i)free and abundant availability of bagasse at local level ii)liberal funding policies by government iii) increasing demand of bagasse by allied markets(pulp and paper industry) and iv) major sugar factories are under severe financial crises. However, social factors provide favourable condition since it offers direct- indirect employment to nearly 2 million workers, and there is also significant indirect employment generation through various services and important human development facilities such as roads, hospital and educational facilities to rural community. The technological factor further offer neutral impact on BCS. There is a scope for technological up-gradation with advanced fourth generation steam engines and energy storage mechanism as discussed in Table 2. The ecological factor seems very crucial for the sustainability of BCS issues like food security, climate change and decreasing water foot print in the sugar belts provides future challenges. Necessary steps as introduced by sustainable sugar growing countries like Brazil and European Union offers favourable pathways. Finally, legal factor put forward favourable impact at BCS the experts were of the opinion that Central and State governments have enacted specific laws for the conservation and protection of RE producers like sugar factories. Such legal fortifications create sufficient conditions amongst the BCS and tender institutional legal framework. Thus, the PESTEL exercise facilitates to assess the contemporary risks and future possible coping strategies for the sustainability of BCS @2030.

The focal aim of the second research question is to explore key influencing factors (KIF's) their inter-

Table 2. PESTEL analysis of Bagasse Cogeneration Sector (BCS) in India @ 2030

FACTOR	POLITICAL	ECONOMIC	SOCIO-CULTURAL	TECHNOLOGICAL	ECOLOGICAL	LEGAL
Factors **FAVOURABLE** to the BCS	i. Condusive/policy/ political environment ii. Strong international cooperation/agreements iii. Special acts/GR's/ incentives for BCS at both national/state level iv. Equal scope/ incentive for private sector's expansion	i. Free/adequate bagasse: economic potency ii. Subsidy/ power purchase agreement iii. Growing investment by private sector iv. Low production cost/ v. Certified Emission Reduction earnings/ CDM	i. Significant share of direct/indirect jobs/CSR ii. Scope for new job opportunities through BCS iii. Positive for HDI/ societal sustainability	i. New plants adopting superior technology (steam/gas) ii. Favourable schemes for technological advancement iii. Private BCS taking lead using second generation technology	i. *Energy by (BCS) is pollution free* and eco-friendly ii. Favourable agro climatic setting ii. Innovative ecological policies(water/ land/seeds)	i. Condusive Law/ Act/GR's ii. Legal protection to energy producers (BCS) iii. Institutional legal frame work iv. Exposure of international law
Factors are of **NEUTRAL** impact on the BCS	i. Long term policy ii. Dynamics between Central/State policy iii. Govt. influence on sugar production/ export	i. Execution of GST ii. Labour/energy costs iii. Growing RE market iv. Competition by private sector SF's	i. Wage rates ii. Migration iii.Sugar consciousness iv. Rural poverty	i. Lack of mechanized sugar harvesting ii. Energy storage iii. Allied infrastructure	i. Land availability ii. Organic farming iii. Air pollutant emissions	i. State laws ii. Legal awareness ii. New amendments
Factors are of **UN-FAVOURABLE** impact on the BCS	i. ISF under strong political influence from local parties/ sugar producers ii. Relative absence of state policy intervention at local iv. Desputes by state agencies to purchase energy through BCS v. Conflicts between Sugar cane growers and State/SF	i. Fluctuations in PPA across states/global ii. Lacks open & competitive market iii. Majority Co-op (SF) under heavy debt burden iv. Seasonal availability of bagasse & it's growing demand by pulp/paper industry	ii. Corruption / bureaucratic delays iii. Lack of skilled workforce/ international exposure iv. Dominance of family management	i. Lacks R & D in BCS ii. Lack of advanced/ hybrid/high pressure technologies iii. Lack of techno-professionalism iv. High techno-capital investment v. Lacks private/ international funding	i. Climate change: droughts, floods, pests, rising temperature, ii. Chemical farming: land salinity/water pollution, low productivity iii. No scope for alternative crop	i. Increased litigations by BCS ii. Subjective interpretation of legal provisions by RE agencies iii. Gap between legal provisions and ground realities
Overall impact	**FAVOURABLE**	**NUTURAL**	**FAVOURABLE**	**NUTURAL**	**NUTURAL**	**FAVOURABLE**
GENERAL CONCLUSION:	In general the (BCS) is favourable, which tends to remain stable despite of varying economic conditions, and technological advancements because of conducive policy and natural environment, however, systematic changes in the sector as a whole will have to be made.					

connections to draw alternative scenarios based on system axis. To operationalize the second research question following multi-stage process was developed: i) at first stage, it was suggested to the respondents to explore common relavant influnesing factors(CRIF's) based on five specefic variables ii) respondents after through interface rounds selected total 22 General relevant influnesing factors (GRIF's) that are crucial for the sustainability of BCS (See Table 3) iii) afterwords, respondents were requested to select key influencing factors(KIF's) out of 22(GRIF's) as reflected in Figure 1 iv) KIF's were then classified into "active/dynamic" and "passive/ buffering" factors/quadrants (Figure 2) v)Finally, factors were measured into system grid/ axis to draw four alternative scenarios and its corresponding specific policy suggestions.

The respondents were asked to rate KIF's in the range of 1-20 scale (20 being highest and 1 being lowest). Accordingly, the respondents were rated to develop KIF's (Figure 1). The five highest KIF's are as follows i) 3 A (score13) renewable energy policy and climate change policy these two variables will have drastic future impact on the BCS sector at both local and national level ii) 2 A (10) global economic developments in terms of import/export minimum support price often becomes crucial for the sustainability of BCS hence policies at national level needs to be framed. iii) 5 B (9) and 1 D (9) both the variables are at par crucial for the sustainability of BCS in India. iv) 4 A (8) the future of BCS will largely be relied on cutting age technological innovations. Therefore, the Indian sugar industry needs to be developed to accommodate fourth generation technological innovations in time bound manner. After identifying KIF's the respondents were guided to develop system grid/axis to draw alternative scenarios in the following manner.

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System grid/axis

The following rationale was applied for the stratification of Key Influencing Factors (KIF's) for developing system grid/axis (see Figure 2).

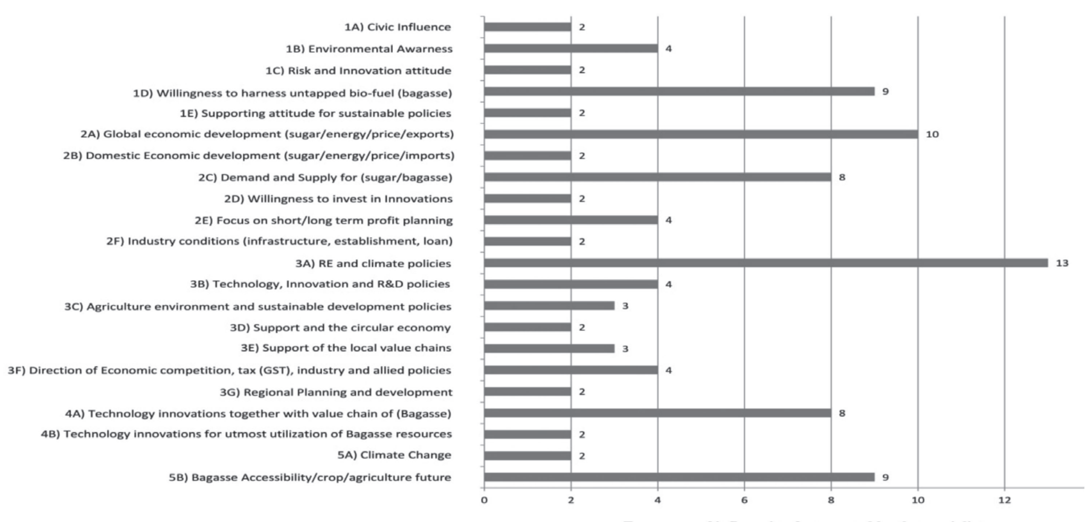

Fig. 1. Key influencing factors (KIF's)

The experts were asked to appraise how (22) influencing factors might affect each other on their interaction. The factors were then classified into "active/dynamic" and "passive/ buffering" factors/ quadrants.

(i)"Active" quadrant: have a major impact on other factors, but are only quietly affected by those other factors themselves.

For instance: Globalisation-2A itself influences many of the factors.

(ii) Dynamic quadrant: have a major impact on other factors, but they are subject to strong external influences.

For instance: Technology innovation and research and innovation policy (3B).

(iii) Passive quadrant: do not display active characteristics, but they are *strongly influenced by other factors*. Due to this feature they are suitable indicators of overall development.

For instance: Demand and Supply of bagasse (2C).

(iv) Buffering quadrant: Potential to *moderate the impact of* (something).

For instance: Bagasse accessibility (5B).

Alternative Scenarios and Policy Suggestions

Based on the through analysis the study put forward the following four scenarios and its corresponding policy suggestions.

Scenario-I

High-Tech Economy – Technology pushes off the limits

This scenario believes that technological innovations go faster beyond current expectations and have impacts (favourable/unfavourable) in the energy supply mix and utilization patterns of an extent similar to the internet's impact in the 1990s.

Policy Suggestion(s)

To harness maximum amount of energy from BC plants advanced and relatively low cost state of art technology is a need of hour. MNRE shall initiate indigenous manufacturing units under 'Make in India' initiatives to develop generation next cost-effective bagasse technology such as: development of

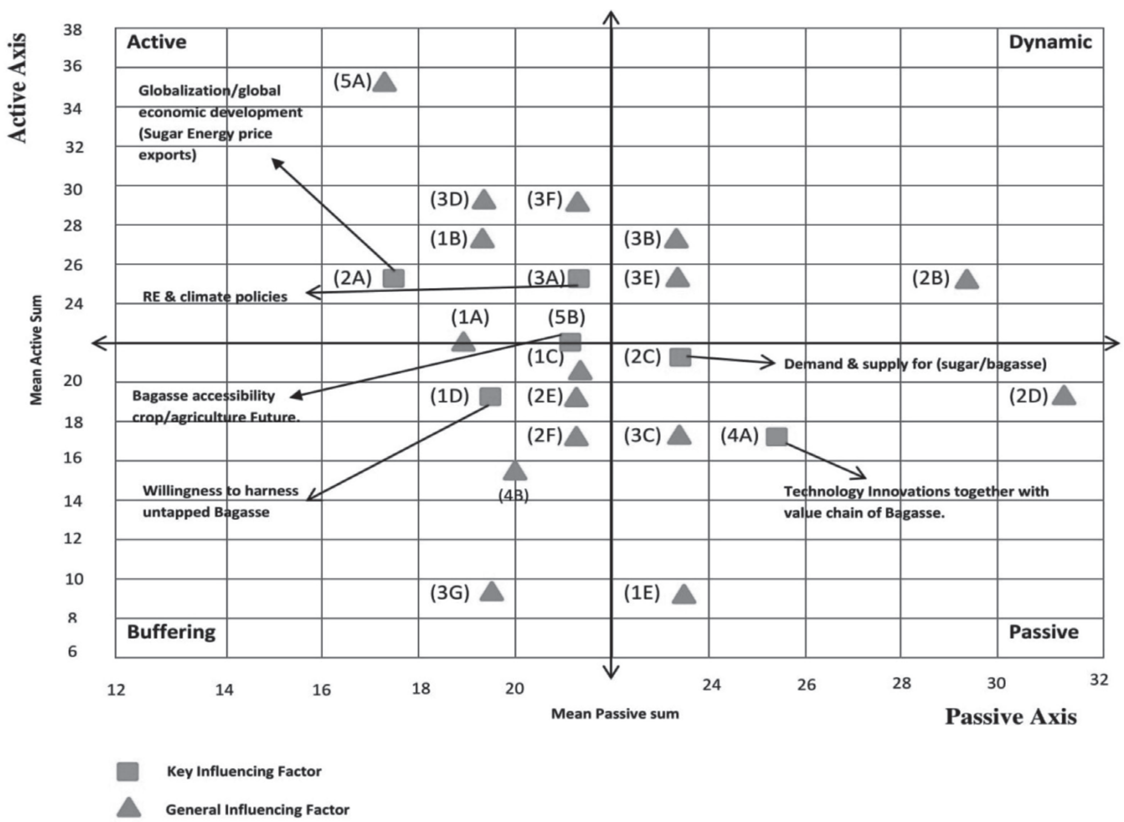

Fig. 2. System grid/axis

hybrid/nano small scale efficient high pressure technology; bagasse and blended biomass cogeneration technology; special funding for technology updating on the basis of merit and outcome; increase approved manufacturers and suppliers region wise (Patil, 2018; Patil, 2020).

Scenario-II

(ii) Multifaceted political-policy tranquillity and reforms

This scenario assumes a state which is oriented towards sustainability and promotes policies conducive to the bagasse however, the reforms leading towards increasing policy overlapping to reach the goals. The tranquillity creates forward/backward imbalances among the different federal states/geopolitical locations.

Policy suggestion(s)

To streamline forward-backward linkages participatory RE policy and expanding relations with stakeholders at the national and overseas is an urgent need. To explore new innovative framework for funding through MNRE, Cogeneration Association of India (CAI), and International Renewable Association (IRA). To encourage reforms through instituting autonomous power producers (APP), developing clusters for BC plants and exclusive bagasse cogeneration sugar zones (BCSZ's). To build lobby and strategic leadership at international level for clean movement like to constitute "International Sugar Energy Industry Alliance-ISEIA. At beginning alliances with established networks like BRICS/ASEAN countries can also be a workable opportunity.

Scenario-III

Environmental and behavioural Backlash

This scenario presumes that environmental concerns (climate change) become more severe and complex, challenges the very accessibility of (sugarcane/bagasse). The backlash (reaction) results in an inevitability to accept sustainable approaches.

Policy suggestion(s)

To sustain sugarcane farming it is crucial to promote sustainable agro policies for instance: sugarcane farmer clubs (SFC); encourage eco friendly

Table 3. General relevant influnesing factors

Variable(s)	General relevant influnesing factors
Society/ Community(5)	1A) Civic influence
	1B) Environmental awareness
	1C) Risk and innovation attitude
	1D) Willingness to harness untapped bio-fuel(bagasse)
	1E) Supporting attitude for sustainable policies
Economy/Sugar/ Bagasse Cogeneration factory(6)	2A) Globalisation/ global economic development(sugar/energy price/exports)
	2B) Domestic economic development(sugar/energy price/imports)
	2C) Demand and supply for (sugar/bagasse)
	2D) Willingness to invest in innovations
	2E) Focus on short term or long term- profit planning
	2F) Industry conditions(infrastructure, establishment, loan)
Politics(7)	3A) RE and climate policies
	3B) Technology, innovation and R&D policies
	3C) Agricultural environment and sustainable development policies
	3D) Support of the circular economy
	3E) Support of the local value chains
	3F) Direction of economic, competition, tax(GST), industry, and allied policies
	3G) Regional planning and development (e.g. responsibility of federal states/regional associations: e.g- Cogeneration Association of India)
Technology(2)	4A) Technology innovations together with value chain of (Bagasse)
	4B) Technology innovations for utmost utilization of Bagasse resources
Environment(2)	5A) Climate change
	5B) Bagasse accessibility/ crop/agriculture future
	Total 22 General relevant influnesing factors have been selected.

land-water conservation initiatives; packages for Organic co-operative sugar farmers associations (OCSFA); special mission for exploring future alternative sugar zones (FASZ's) in collaboration with Indian Space Research Organizations (ISRO); enacting 'Sugarcane Farming Drip Irrigation Act' (SFDIA) for the overall sustainability of BCS in India.

Scenario-IV

The sceptical economic threshold

This scenario assumes that the current pace of economic patronage by state for (BCS) will not be sustained. The dynamics of cooperative sugar factories remain same without great surprises or much change in energy sources. However, the doubtfulness of change in this sector paves way for higher degree of privatization of (BCS).

Policy suggestion(s)

Towards the economic sustainability of BCS in India it is suggested that government may endorse 100 % FDI and self regulated financial mechanism to support structural reforms and tax restructuring. The economic patronage to the co-operative BCS has to disburse on the basis of performance and tangible outcome based indicators. Meanwhile, sugar federations needs to be accountable, improve managerial and technical skills mainly at old and medium TDI co-operative sugar factories; encourage competition amongst the co-operative and private BCS through capital incentives and develop innovative ways for energy storage, transfer and additional energy production.

Conclusion

Constructing sustainable energy policies and to assist policy makers by means of forecasting appropriate policy measures are significant component of policy making especially in the post climate change era. Moreover, sustainable policy making is primarily relied on analysing future consequences and their intricacies. Therefore, considering the complexities in India's socio-ecological and political milieu the present study was specifically conducted to provide concrete insights to policy makers for constructing sustainable policies in the renewable energy sector by exploring alternative future scenarios and specific policy implications in the area of BCS in Indian sugar industry. This study is perhaps the earliest effort to empirically attempt to fill up the aforementioned policy gap by applying futures methodology. The study draws four concrete scenarios which provide solid starting point and orientation to the concerned stakeholders connected with BCS. Thus, bearing in mind the instantaneous and foreseeable future that is (2030) for (BCS) it is concluded that, based on the policy suggestions systemic structural changes in the sector as a whole have to be made in order to provide sustainable policy solutions to the BCS in Inda.

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