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Path to Decarbonisation: Strategies for Realising Tamil Nadu's Green Hydrogen Potential

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Key Policy Recommendations

In order to realise its green hydrogen ambitions, we identify the following actions for TN.

- Define the scope of renewable fuels and identify key sectoral priorities at an early stage.
- Implement focused training and development programmes to upskill workforce from petroleum and other similar industries, creating a workforce for the green hydrogen economy.
- Conduct comprehensive cost analyses for green hydrogen and green ammonia to ensure economic viability and inform policy formulation.
- Assess the socioeconomic impact of green hydrogen projects to ensure effective community engagement and participation in the decision-making process.
- Explore the use of industrial wastewater/brine for green hydrogen, rather than freshwater.
- Ensure the availability of electrolysers to encourage industrial adoption of green hydrogen.

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Summary

Tamil Nadu (TN), a southern state in India, aims to establish itself as a 'Green Hydrogen Hub' by fostering domestic consumption, developing essential infrastructure, and facilitating the export of green hydrogen to other Indian states and international markets. This ambition is aided by a high offshore wind potential of 35 GW, primarily from south-eastern coastal regions which provide significant opportunities for harnessing wind energy. This offshore wind power generation can then be used to produce green hydrogen leading to decarbonisation.

To better understand prospects and challenges in TN's green hydrogen strategy, this briefing identifies (i) barriers to H_2 uptake, (ii) research requirements, (iii) upskilling needs, and (iv) socioeconomic adoption for the green hydrogen economy in TN. These findings are drawn from interactions with 47 key stakeholders from academia, governments agencies, technical consultancies, NGOs, and the private sector through a combination of an interactive green hydrogen workshop and expert interviews.

Hydrogen Status

Climate change has prompted the need for the rapid adoption of new and emerging technologies. In 2015, the global community committed to taking action to keep global temperature rise well below 2°C in relation to preindustrial levels [1]. However, achieving complete decarbonisation of economies will require concerted and wide-ranging action across all economic sectors.

The rise of technologies such as solar and wind power, lithium-ion batteries, and alternative fuels has paved the way for decarbonisation in various end-use sectors [2]. However, there are certain sectors like steel, cement, chemicals, long-haul road transport, maritime shipping, and aviation that are hard to decarbonise using the aforementioned renewable technologies [3]. Green hydrogen (ie hydrogen (H_2) produced using renewable electricity through electrolysis, hereafter referred to as GH_2), might be a solution to decarbonise these sectors.

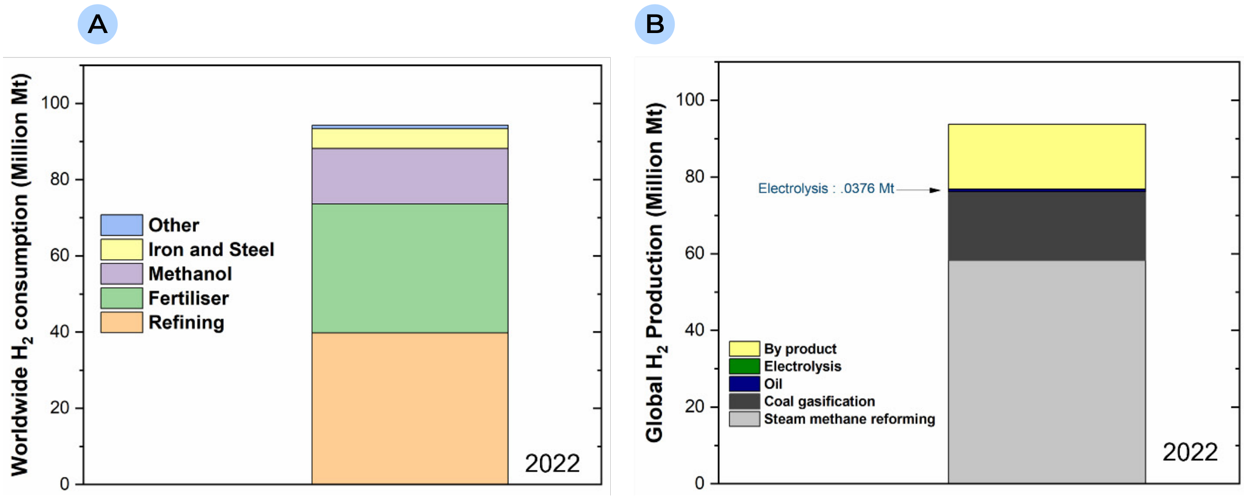

Figure 1.1. Global hydrogen (a) demand by sector, and (b) by manufacturing process in 2022. Adapted from [4]

Presently, H_2 is used in a variety of applications around the world, including as a chemical feedstock (eg, ammonia, methanol, hydrochloric acid) and a component in various industrial processes (refining oil and gas). The existing global annual demand of H_2 as of 2023 is 94 million Mt and most of it is concentrated in the refining and fertiliser sectors [4]. Only 0.04% of this H_2 is currently being produced by electrolysis, while the rest is mostly produced by steam methane reforming and coal gasification (ie, grey H_2) [4] (**Figure 1.1**). Furthermore, around 70% of hydrogen production is captive, where hydrogen is produced and used on site [4, 5].

To date, more than 30 countries across the world have formulated strategies for a GH_2, including financial incentives to accelerate the transition. Similarly, India, in 2021, announced plans to become a global hub for GH_2 [6].

India's GH_2 mission

In 2021, India unveiled its GH_2 policy, signalling an intent to be a global hub for GH_2 production [7]. Key expected outcomes by 2030 are:

1. Annual GH_2 production capacity to 5 million Mt
2. Renewable energy capacity addition of 125 GW
3. Total investment of £80 billion in hydrogen economy
4. Creation of 600,000 jobs
5. 50 million Mt of CO_2 emission reduction annually.

The allocation for GH_2 production and electrolysers from India's government is £1.74 billion, representing 88% of the financial support [8] [9]. Recently, India announced that hydrogen can be classified 'green' when well-to-gate (water treatment, electrolysis, gas purification, drying and compression) greenhouse gas emissions are less than 2 Kg of CO_2 equivalent per kilogram of H_2 produced [10]. According to NITI Aayog, an Indian public policy thinktank, India has some of the most competitive Levelised Cost of Electricity (LCOE) rates for solar and wind (Rs. 2/kWh) in the world, while remaining a net importer of natural gas [8].

This makes GH_2 production costs in India highly competitive compared to the rest of the world. The levelised cost of green hydrogen (LCOH) production in India, approximately $5 per kilogram [8], is slightly higher compared to regions with higher GH_2 production potential, such as Morocco, where it stands at around $4 per kilogram [11]. However, according to a recent report by the International Renewable Energy Agency, India is projected to become one of the regions with the lowest LCOH for green hydrogen by 2050, estimated at $1.4 per kilogram [12]. Also, India has high hydrogen domestic demand, owing to existing industrial processing including large-scale steel, fertiliser, and petroleum refineries (**Figure 2.1a**). How different sectors contribute to this demand is shown in **Figure 2.1b**. These sectors have a high carbon footprint, and their decarbonisation will significantly impact India's journey towards achieving its net-zero goals. The overall demand in India for hydrogen from the industry, transport, and power sectors is expected to be over 25 million Mt by 2050, with the majority fulfilled by GH_2 [13]. According to International Energy Agency estimates, nearly 20 GW of electrolysers are planned in India by 2030 [14].

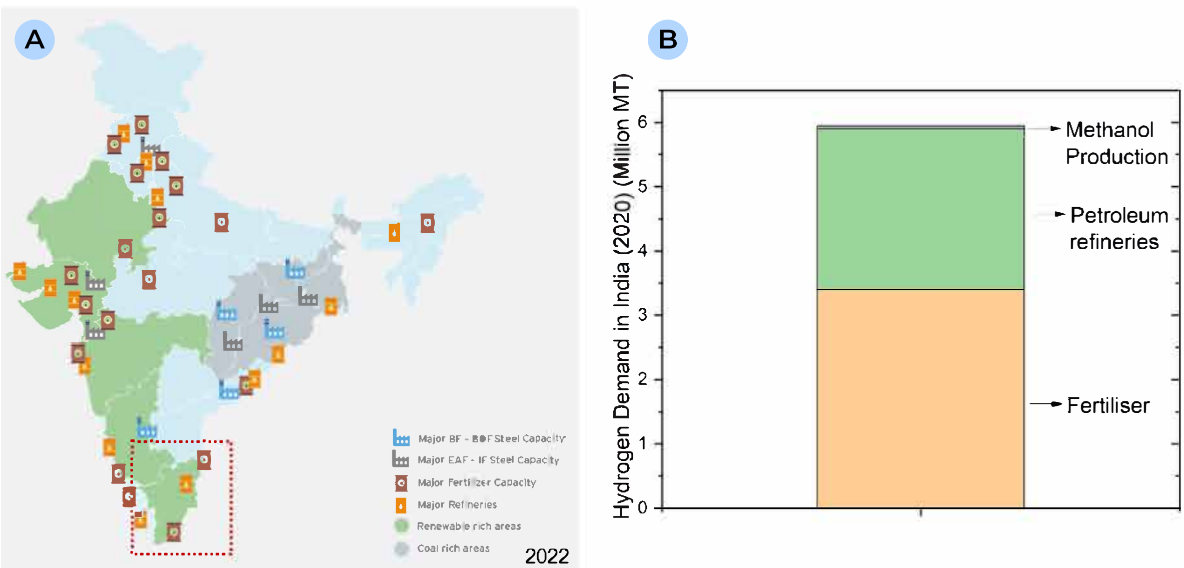

Figure 2.1. (a) Location of key industrial facilities in India (Tamil Nadu in Red dotted square). Reproduced from [8] and (b) Hydrogen demand projection in the Low-carbon scenario, 2020–2050. Reproduced from [13].

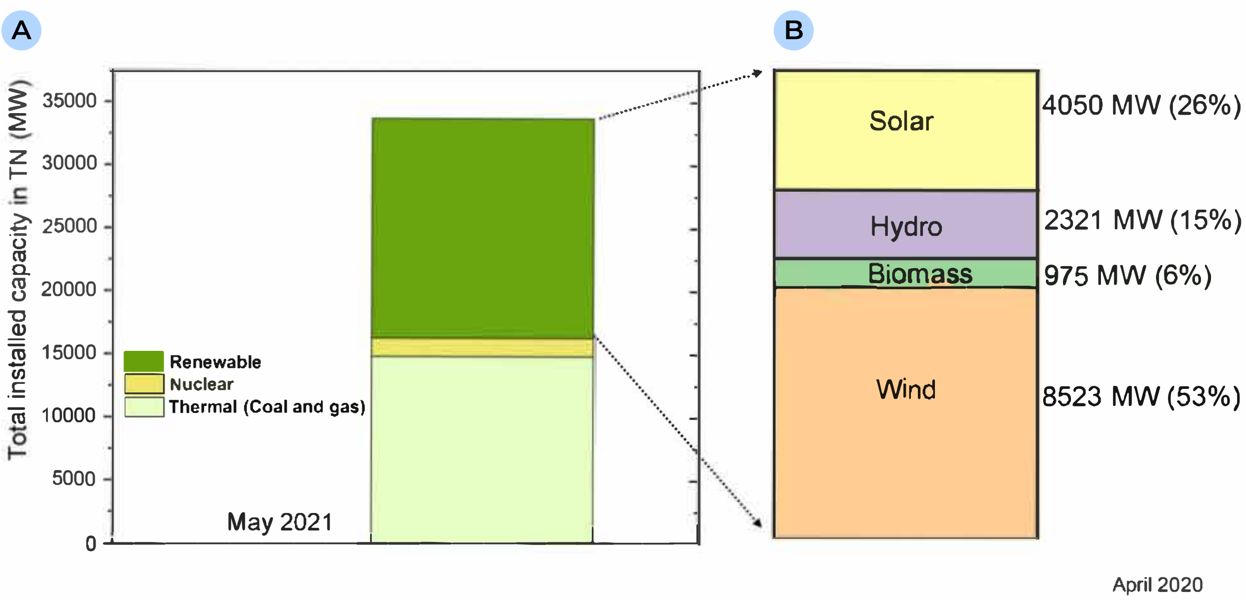

Figure 3.1. Energy composition of Tamil Nadu (a) overall and (b) renewables [17].

Tamil Nadu's GH_2 ambition

Tamil Nadu's GH_2 ambition is within the context of India's 'National Green Hydrogen Mission' [7]. Tamil Nadu (TN), being one of the most industrialised states in India, has an electricity consumption of 18 GW as of 2022. The contribution of green energy to the TN grid is 21%, and this is estimated to increase to 50% in 2030 [15]. The installed renewables capacity constitutes 44% of overall capacity (**Figure 3.1a**). Moreover, wind power constitutes more than half of total installed renewable capacity (**Figure 3.1b**). The cost of renewable electricity in TN is already lower than competing sources such as coal, oil, and gas. In addition, TN has a 1,000 km long coastline with average windspeeds of 7 m/s, and it is estimated that this translates to 35 GW of untapped offshore wind potential [16] (**Figure 3.2**). The TN government has planned a GH_2 hub at the southern port of Tuticorin, with the aim of utilising renewables to produce low-cost GH_2 (shown by the black arrow in **Figure 3.2**). TN has set a target of 2 million Mt annual production of GH_2 by 2030 and has already attracted investments from multiple private companies.

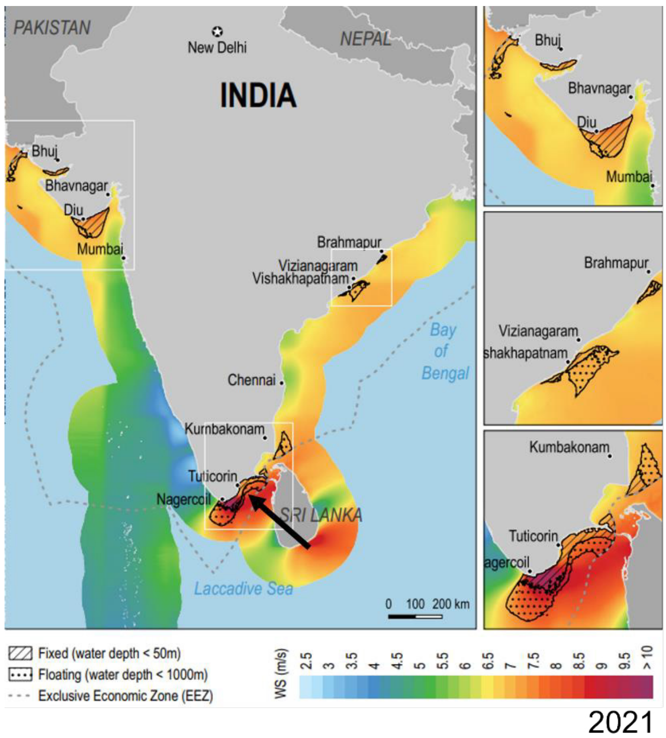

Figure 3.2. Offshore wind potential of Tamil Nadu. Black arrow indicates southern port of Tuticorin in Tamil Nadu. Offshore wind can become a cost-effective option for hydrogen production at high full load hours. Reproduced from [18].

Methodology

While India has introduced a national GH_2 policy, the specific implementation at the state level, like in the case of Tamil Nadu, lacks clarity regarding the alignment of state policies with national goals. Additionally, uncertainties persist regarding the technoeconomic and socioeconomic aspects of GH_2 economy due to its novelty. Consequently, to gain insights into the potential opportunities and challenges associated with GH_2, we engaged and consulted 47 stakeholders (composition in **Table 4.1**) – from policy makers to industry experts and academics – through expert interviews, and a participatory workshop. These methods are discussed below.

1. **Green hydrogen workshop:** 37 stakeholders participating in a workshop were requested to fill in an online questionnaire on GH_2 to allow systematic collection of insights. The questionnaire consisted of a total of 21 questions, incorporating both multiple-choice and open-ended formats. In addition, the workshop also included an interactive session where participants were split into five groups to discuss:
   i. Challenges and barriers to the widespread adoption of GH_2 cross-disciplinary efforts
   ii. Research needed to realise GH_2 goals
   iii. Community engagement
   iv. Measures of success in the context of GH_2
2. **Expert interviews:** 10 expert interviews were conducted to gain insights into the current state of GH_2. Most of these experts participated in the survey questionnaire and workshop.

Type of stakeholder	Number	Abbreviation in text
Consultant	7	CON
Researcher	8	RES
Policymaker	13	POL
Project developer	11	PRD
Government officer	8	GovO

Table 4.1. Compositions of stakeholders

Results and Discussion

From the primary research – the interactive GH_2 workshop and expert interviews – six key themes emerged, which are discussed below. These themes were barriers to GH_2 adoption, the skills needed, sectoral priorities, the research gaps, the need for community engagement, and how to measure success.

Barriers

The barriers to GH_2 adoption were clearly identified from a wide range of factors. From a technological viewpoint, low round-trip efficiency (29% [19]) of GH_2 (percentage of energy converted into hydrogen through electrolysis, stored, and then converted back into usable energy) was reported to be a barrier. This is directly linked to electrolyser efficiency. A significant policy obstacle for GH_2 was the lack of a clear pathway for GH_2, arising from the nearly simultaneous announcement of competing renewable energy policies, such as the promotion of methanol, ethanol and electric vehicles. Additionally, the lack of defined sectoral priorities and absence of well-defined mandates were recognised as another hindrance. Notably, stakeholders from the private sector highlighted the lack of available cost-effective electrolysers, which were deemed crucial for decarbonising the private sector. From the perspective of material costs, the necessity for demineralised water for electrolysis was identified as a potential barrier.

“*There are too many policies too quickly*” (CON1)

Other barriers that emerged during discussion included the absence of round-the-clock renewable electricity and inadequate GH_2 storage infrastructure. Lastly, a lack of the skills required for a GH_2 economy was also highlighted as a barrier.

❝ *The vision document of the government should be well permeated* ❞ (RES)

Skills

Stakeholders proposed that it is essential to (i) introduce dedicated courses at the undergraduate/postgraduate levels, (2) enhance the expertise of professionals in industries such as oil and gas, and (3) implement focused initiatives for young individuals (**Figure 5.1**). These initiatives were deemed necessary to cultivate the skill sets required for the advancement of the GH_2 economy.

❝ *There is a lack of critical mass for (green) hydrogen* ❞ (CON2)

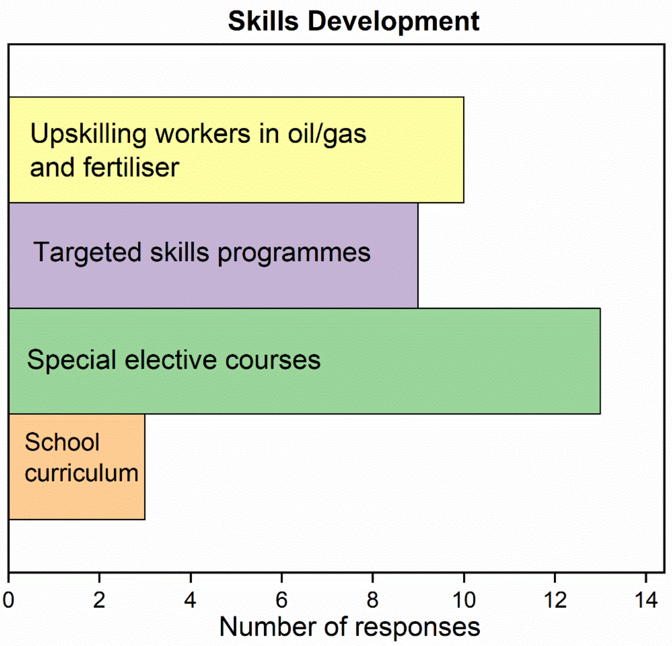

Figure 5.1. Ranking relevance of skills development for GH_2 economy in TN

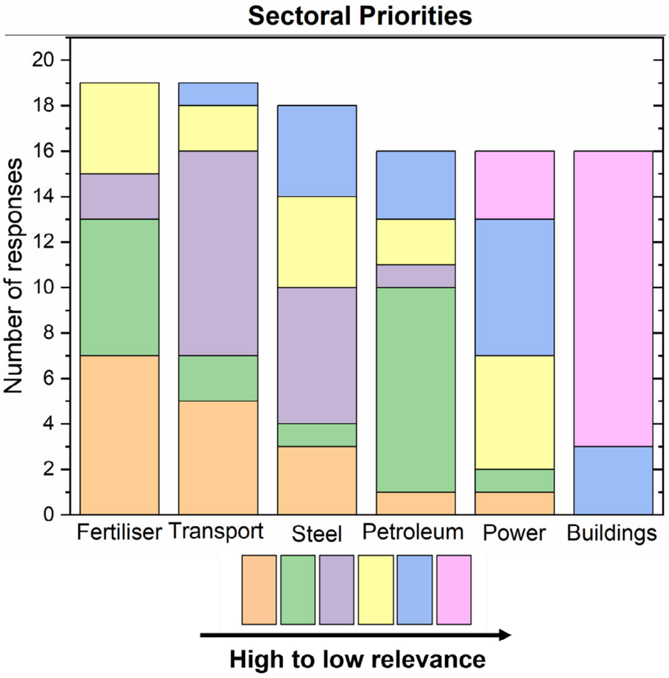

Figure 5.2. Ranking sectoral priorities in six key sectors: Agriculture, Transport, Industry, Petroleum, Power, and Buildings.

Sectoral priority

Stakeholders were asked to rank sectors by their relevance to the GH_2 economy. The agriculture sector (fertiliser) was clearly identified as the sector with most relevance. This was followed by the transport, steel, petroleum, and the power sector, in this order. The buildings sector was identified as the lowest priority sector (**Figure 5.2**).

Research needed to realise goals

Stakeholders emphasised the significance of conducting comprehensive analyses regarding the costs and supply chain intricacies associated with the GH_2/Green ammonia production. This was deemed essential for ensuring financial viability and policy formulation. Furthermore, the evaluation of sector-specific projections for GH_2 demand was considered crucial in order to effectively assign mandates to various sectors. Additionally, stakeholders underscored the importance of adopting GH_2 utilisation in transport (eg long-haul freight), as a pivotal step towards decarbonising the transport sector.

Stakeholders also conveyed the necessity of investigating the potential use of industrial wastewater/saline water as an alternative to freshwater for GH_2 production.

❝ *Research is needed to justify infrastructure to support initial investments* ❞ (POL)

Community engagement

A prominent takeaway from stakeholders was the importance of ensuring that the advantages of GH_2 are readily apparent to the general population. This was seen as critical for the broad acceptance of hydrogen technologies (eg hydrogen powered buses). Therefore, it is crucial to effectively communicate the positive effects of GH_2 for public health and the creation of employment opportunities. In alignment with this goal, stakeholders highlighted that it is essential for Tamil Nadu's vision document and findings from flagship projects to be easily accessible to the public.

❝ *Easy, progressive science communication is needed* ❞ (GovO)

Measure of success

When asked about what stakeholders perceive as success with regards to GH_2 ambitions, stakeholders indicated the following criteria for measuring success: (1) reduction in emissions, (2) number of jobs created, (3) share of hydrogen in local energy usage, and (4) research evidence generated to support infrastructure development.

Conclusions and Recommendations

Following on from the workshop and consultation with stakeholders, we recommend the following steps for Tamil Nadu (TN) to realise its GH_2 ambitions and decarbonisation goals.

Green hydrogen needs effective policy and early adopters to lead the way

1. TN has already begun its journey on GH_2, since India's GH_2 mission was announced in 2021. In this regard, the scope of renewable fuels (hydrogen, ethanol, and methanol) should be clearly defined, and the sectoral priorities clearly identified in the initial stage. The TN Government vision document for GH_2 should be published and well circulated with timelines, material availability, and cost economics.
2. A rapid skills development programme across the ecosystem, including government, industry, and academia, should be developed. TN already has rich human resources within the fertiliser and refinery sector. A smooth transition for existing workers in refineries and fertiliser to GH_2 should be facilitated. Also, GH_2-related course electives should be offered in undergraduate and postgraduate courses in universities to create a talent pool.
3. Detailed cost analysis of GH_2 and green ammonia is necessary for economic viability and policy formulation.
4. Socioeconomic impact assessments of GH_2 projects are important for effective community engagement and participation.
5. Industrial wastewater/brine for GH_2 should be explored as an alternative to freshwater as water is a scarce commodity in TN.
6. The availability of affordable electrolysers is important from an industrial viewpoint for on-site production of GH_2 and production of GH_2 in general in TN.

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Climate Compatible Growth

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