# Pakistan to send Minister to India for SCO dialogue

Musadik Masood Malik has been a vocal critic of India's decision to place Indus Waters Treaty in abeyance after Pahalgam attack; Pak. says committed to promoting dialogue among civilisations

**Kallol Bhattacherjee**
NEW DELHI

Pakistan's Federal Minister for Climate Change and Environmental Coordination, Musadik Masood Malik, will represent his country at the Shanghai Cooperation Organisation (SCO) Civilisational Dialogue to be held here from November 20 to 22, Islamabad announced on Saturday.

Mr. Malik has been a vocal critic of New Delhi's decision to place the Indus Waters Treaty "in abeyance" following the April 2025 Pahalgam terrorist attack. The last Pakistani Minister to visit India was Bilawal Bhutto Zardari, who had visited Goa in May 2023 for the SCO Foreign Ministers meeting.




*The Hindu* reported on October 28 that the Indian government had invited Pakistan's Minister for National Heritage and Culture, Aurungzeb Khan Khichi, to attend the SCO Civilisational Dialogue event, the first such Ministerial-level invitation since 2023. However, the Pakistani government has nominated a different representative.

"The Government of Pakistan remains committed to promoting dialogue among civilisations and fostering people to people contacts within the SCO framework in a spirit of mutual respect," the Pakistan government said in a statement on Saturday.

India and Pakistan engaged in military hostilities after the terror attack in Pahalgam, following which India placed the 1960 Indus Waters Treaty "in abeyance". Mr. Malik, a technocrat-turned-Minister, said in a press conference in June this year that Pakistan would "cut off those hands" that are attempting to control the Indus waters. Asserting its claim on the Indus, Pakistan has been highlighting the Indus Valley civilisation of Mohenjo Daro and Harappa and other ancient sites in the country in recent months.

CONTINUED ON » PAGE 7

GS 2: International Relations

Key Pointers:

- India- Pakistan Relations
- What is SCO?
- Members of SCO
- SCO Civilizational Dialogue
- What is Indus Water Treaty?
- Pahalgam terror attack

## From Page One

# Pak. to send Minister to India for SCO dialogue

On World Heritage Day on April 18, Pakistan Prime Minister Shehbaz Sharif had referred to the Indus Valley civilisation in his remarks, saying, "Pakistan's cultural heritage is enriched with a multifaceted civilisation. Our homeland carries the legacy of some of the world's oldest civilisations, reflecting a vibrant tapestry of human creativity and diversity."

**'Shared civilisational past'**

On Friday, Union Culture Minister Gajendra Singh Shekhawat said India and Pakistan have a shared "civilisational and cultural" past, adding that New Delhi hopes that Pakistan will attend the upcoming SCO Civilisational Dialogue.

"I believe that Pakistan's civilisational and cultural progress is no different from ours," Mr. Shekhawat said, in response to a question about the invitation, given the tensions with Pakistan. "They [Pakistan] separated from us less than 100 years ago, but prior to that, we [India and Pakistan] have evolved together. So we should not have any differences over these issues," he added.

Mr. Shekhawat said that the purpose of the SCO Civilisational Dialogue, first proposed by Prime Minister Narendra Modi, was to see how the SCO could "go a step beyond geopolitical, strategic and bilateral relations and strengthen our cultural ties so that in the future we can have better relations and communications between the people of our countries."

Soon after Mr. Shekhawat's comments, however, the Ministry of External Affairs said that India would follow "national policy" regarding Pakistan in view of the Pahalgam terror attacks, indicating that it may not grant Punjab Chief Minister Bhagwant Singh Mann clearance to attend an international Punjabi cultural conference in Lahore at the end of the month.

AMRITA IAS

# Quad leaders to meet in Philippines on Tuesday

**Suhasini Haidar**
NEW DELHI

Prime Minister Narendra Modi will meet U.S. President Donald Trump and the leaders of Japan and Australia at the first Quad summit since 2024, on the sidelines of the ASEAN Summit in Manila, the Philippines, on Tuesday, sources said. The meeting will be the first to be held in a non-Quad country.

**FULL REPORT ON**
» **PAGE 7**

# Quad summit likely to be held in Manila on Nov. 17

It is for the first time that the summit will be held in a non-member country; supply chains for critical minerals, securing commercial shipping lanes for energy supplies likely on the agenda

**Suhasini Haidar**
NEW DELHI



**Leadership meet:** The confirmation of the summit is significant for the Indo-Pacific grouping. REUTERS

Prime Minister Narendra Modi will meet U.S. President Donald Trump, Japanese Prime Minister Sanae Takaichi, and Australian Prime Minister Anthony Albanese at the first Quad summit since 2024, on the sidelines of the ASEAN Summit in Manila, Philippines, next week, sources said.

According to the sources, the meeting is expected to take place on the evening of November 17.

While the confirmation of the Quad summit is significant for the Indo-Pacific grouping, much of the attention will be taken by Mr. Trump's pronouncements at his next stop in Shenzhen, China, where he will hold the first-ever three-way summit with Chinese President Xi Jinping and Russian President Vladimir Putin on November 19, to discuss global issues including nuclear arms control.

In Washington, U.S. officials briefing the media on Mr. Trump's travels also confirmed that he would travel to Manila and take part in, among other meetings, a "multilateral meeting" with the leaders of the Quad countries, news agency Reuters reported.

**On the agenda**

The agency quoted briefing by unnamed officials, who said that supply chains for critical minerals and securing commercial shipping lanes for energy supplies would be a key part of the agenda. "The issue of attacks on commercial ships is very likely to be taken up," the unnamed official quoted by Reuters said. The safety of ships and seafarers has been a particularly important issue for India, as at least 30 Indian seafarers aboard ships in the Strait of Hormuz, the Sea of Oman, and the Black Sea have been killed in attacks during the conflicts in Iran and Ukraine, respectively. Earlier, reports had indicated that a Quad Business Forum mechanism would also be announced during the summit.

The Manila meeting will be the first Quad summit being held in a non-Quad country and indicates the challenges that India has faced as the chair of the summit of the four-country grouping that revived its cooperation in the Indo-Pacific in 2017 and upgraded it during the COVID-19 pandemic in 2021 to leader-level meetings. Since then, the government has been unable to host the Quad summit in India even once, mainly due to the U.S. President's unavailability. New Delhi is unwilling to hand over the chairship of the summit without hosting it in the Indian capital, which may yet happen next year, sources said.

Officials did not clarify who would act as the official host of the meeting in Manila, which has been discussed for weeks, including during U.S. Secretary of State Marco Rubio's visits to India this year. The U.S. midterm election results had delayed the confirmation of Mr. Trump's travels to the Philippines for the East Asia Summit and to China for the Asia Pacific Economic Cooperation Summit.

Ministry of External Affairs spokesperson Randhir Jaiswal on Friday told presspersons only that the Ministry would "keep [them] updated with developments in Manila pertaining to the Quad".

GS 2: International Relations

Key Pointers:

- What is QUAD?
- Members of QUAD
- What is ASEAN?
- Is India a member of ASEAN?

# ECI assures SC of measures in place to enrol voters deleted by mistake

**Krishnadas Rajagopal**
NEW DELHI



The Election Commission of India (ECI) on Saturday filed a supplementary affidavit in the Supreme Court detailing "further measures" in place to ensure that voters who have been wrongly left out as "absent, shifted, dead or duplicate" from the draft electoral rolls are brought back in.

"The Commission remains alive to the need to ensure that all those who are eligible to vote find their name in the voters' lists," the ECI assured the public.

It said directions have been issued on November 6 to the Chief Electoral Officers of States and Union Territories where the special intensive revision (SIR) was under way to allow such voters to submit the duly-filled Enumeration Form (Annexure A) to the ERO or AERO communicating their current ordinary residence.

"Electors who have not shifted may submit the signed Enumeration Form (Annexure A) with the Annexure-B statement giving the reason for the earlier non-submission of the Enumeration Form. They can submit it to the ERO/ AERO/ BLO in person or through family members. Online submission option with e-sign will be available on the ECINET," the affidavit said.

For electors who have shifted within the State, and were found to be excluded from the draft roll, Form 8 (for shifting) is not required. "They can submit the Enumeration Form (Annexure A) with the Annexure-C statement (giving their new address and Assembly Constituency) and address proof to the ERO / AERO of the new constituency. They can also use the 'Book a call with BLO' facility, among others which are self-explanatory," the ECI noted.

The poll body informed the court that instructions have been given out to provide booth-wise lists of left-out electors (voters marked as absent, shifted, dead or duplicate or ASDD) to be displayed afresh along with the "probable reasons" for non-inclusion.

"The Enumeration Forms submitted by such electors shall be processed by the EROs in accordance with Rule 21(1) of the Registration of Electors Rules, 1960 [for inclusion of names inadvertently omitted from the electoral roll] and the same EPIC number shall be re-assigned to them," the affidavit clarified.

However, any previously-registered elector, who was deleted from the draft roll, but had already submitted Form 6 [application for new voters], need not submit the Enumeration Form afresh. Their applications would be processed in accordance with the November 3 clarification on re-inclusion into the electoral roll without the fear of facing any criminal prosecution.

"A mechanism has also been directed to be put in place to ensure that no elector is deprived of the opportunity to get his/her name included in the final electoral roll, subject to fulfilment of the prescribed eligibility conditions, while taking due care to avoid duplication in enrolment," the EC submitted.

GS 2: Polity

Key Pointers:

- What is SIR?
- Functions of ECI
- What is ECINET?
- What corrective measures has the ECI introduced?
- Representation of the People Act, 1950

# India backs UN resolution on rights of Palestinians

**Press Trust of India**
UNITED NATIONS

India has voted in favour of a UN General Assembly draft resolution that reaffirms the inalienable rights of the Palestinian people and the population of the occupied Syrian Golan over their natural resources and demands that Israel cease the exploitation and damage of these resources.

The 193-Member UN General Assembly voted overwhelmingly on Wednesday in favour of the resolution 'Permanent sovereignty of the Palestinian people in the Occupied Palestinian Territory, including East Jerusalem, and of the Arab population in the occupied Syrian Golan over their natural resources' proposed by Uruguay. India voted in favour



The UN General Assembly voted overwhelmingly in favour of the resolution.

of the resolution along with 150 other UN Member States, while Israel and the U.S. were among the seven nations that voted against the draft, which got 11 abstentions.

The resolution reaffirmed the inalienable rights of the Palestinian people and of the population of the occupied Syrian Golan over their natural resources. It demanded that Israel "cease the exploitation, damage, cause of loss or depletion and endangerment of the natural resources in the Occupied Palestinian Territory, including East Jerusalem, and in the occupied Syrian Golan.

It stressed that the wall and settlements being constructed by Israel in the Occupied Palestinian Territory, including in and around East Jerusalem, are contrary to international law and seriously deprive the Palestinian people of their natural resources.

The resolution called upon Israel to comply strictly with its obligations under international law and immediately and completely cease all policies and measures aimed at altering the character and status of the Occupied Palestinian Territory, including East Jerusalem.

GS 2: International Relations

Key Pointers:

- What is the resolution about?
- What is the significance of India's vote?
- What is the significance of the occupied Syrian Golan?
- What is the role and limitation of the UN General Assembly?

# Air passenger traffic takes a hit, down 2.9% in April-Sept.

The decline in passenger traffic has been accompanied by a fall in aircraft movement, with airlines having found it more economical to ground planes than operate them due to costly aviation fuel

Jagriti Chandra
NEW DELHI

Air passenger traffic in India has slipped into contraction, declining 2.9% in the April-September period, with international travel taking a bigger hit than domestic flying. While domestic passenger traffic fell 1.9%, international traffic was down a sharper 7.1%.

The slowdown comes at a time when airlines are grappling with the fallout of the conflict in West Asia. Higher aviation turbine fuel costs, airspace disruptions and longer flight routes have added to operating expenses, forcing airlines to trim capacity or flights and raise fares. The resulting increase in travel costs may also be weighing on passenger demand.

The weakness follows a year of near-stagnant growth. In FY2025-26, passenger traffic grew by just 1.9%, with domestic travel barely inching up and international traffic doing somewhat better. This marked a sharp deceleration from the double-digit growth recorded in the years immediately after the pandemic.

All passenger figures are from Airports Authority of India's monthly passenger traffic data that calculates both arriving and departing passengers across all airports.



While domestic passenger traffic fell 1.9%, international traffic was down a sharper 7.1% in the April-September period. FILE PHOTO

**Reduced flights**

The decline in passenger traffic has been accompanied by a fall in aircraft movements, pointing to a reduction in the number of flights operated by airlines.

This reflects not only cancellations of international services but also capacity rationalisation on domestic routes, where some airlines have found it more economical to ground aircraft than operate them amid higher aviation turbine fuel (ATF) costs. Aircraft movements – counting each landing and take-off – fell 3.5% in April-September compared with the corresponding period last year.

According to IndiGo CEO William Walsh in a post-results analyst call last month, the airline is seeking to strike a balance between yield management, or the revenue earned per passenger for every kilometre flown, and load factor, or the proportion of seats occupied on an aircraft, to maximise revenue.

This means airlines are willing to let some seats go unsold if that helps them maintain higher fares and maximise overall revenue. IndiGo's revenue per seat kilometre saw a growth of 34% but seats sold saw 2-percentage point reduction. Across the industry, there were 5% fewer seats in the July-September period.

In October, average airfares were a massive 43% higher compared to the same month last year, according to Consumer Price Index. Of all the 358 goods and services in the CPI basket, airfares saw the largest increase in price (13.36%) from the previous month. In September, airfares were 29.9% higher compared to the same time previous year. "But demand has held up pretty well" even at the inflated airfares, Mr. Walsh said about the months of July-September.

**ATF prices**

India's ATF prices have risen sharply since the escalation of tensions in the Gulf in February 2026. In Delhi, the price for domestic airlines has climbed from approximately ₹91.39 per litre in February to ₹138.50 per litre in November.

From April 1 to June 8, the government had capped the ATF price increase for domestic airlines at 8.5%, limiting the pass-through of an international price shock that would otherwise have more than doubled fuel prices to approximately ₹2.07 lakh per kilolitre.

GS 3: Economy

Key Pointers:

- What is the present situation in India's aviation sector?
- Why is India's aviation sector facing a slowdown?
- What is UDAN (Ude Desh ka Aam Nagrik)?
- What is Aviation Turbine fuel?

# India to contribute €7 million to Italian research facility

Jacob Koshy
NEW DELHI

**Indian scientists have conducted research at Elettra since 1998 and continue to use its facilities**

India has committed to contribute at least €7 million (approximately ₹73 crore) over the next five years, beginning in the current financial year, towards the Elettra 2.0 programme, Union Science Minister Jitendra Singh said in Italy on Saturday.

Elettra Sincrotrone Trieste is an international research centre in Trieste, Italy, that operates a synchrotron light source – a facility in which electrons are accelerated to nearly the speed of light and made to emit extremely bright X-rays and other forms of electromagnetic radiation. These beams allow scientists to examine the structure and properties of matter at the atomic and molecular scales, with applications ranging from materials science and nanotechnology to biology, medicine, archaeology, and cultural heritage.

The centre operates two major facilities: Elettra, a third-generation synchrotron light source, and FERMI, a free-electron laser that produces exceptionally bright, ultrashort light pulses.

Its scientific importance lies in giving researchers access to experimental tools that can reveal the structure, composition, and behaviour of matter with extraordinary precision, including processes occurring over extremely short timescales.

**Scientific partnership**

India's participation will support the development of research infrastructure and human resource capacity, marking a "significant new phase" in the longstanding scientific partnership between India and Italy, an accompanying press statement noted.

India and Italy have collaborated on research for at least 25 years, with Indian scientists having conducted research experiments at Elettra since 1998 and continuing to use its facilities. India is currently the second-largest user of Elettra after Italy, reflecting the sustained engagement of its scientific community.

Around 1,100 proposals for experiments were received by Elettra from Indian research groups. India ranks second in the number of proposals submitted, after Italy.

GS 3: Science and technology

Key Pointers:

- What is the Elettra Sincrotrone Trieste facility?
- What is a synchrotron light source?
- What are the two major facilities at Elettra?
- Why is India's participation significant?

# Anthropic's valuation can't secure its moat

Its engineers need to keep building progressively more capable models; the AI firm has also not established that it will be able to sustain its profitability after honouring its infra commitments. neither Anthropic nor its competitors, has a lasting competitive advantage, a.k.a. a moat

Vasudevan Mukunth
CHENNAI

Artificial intelligence (AI) company Anthropic, best known as the maker of the Claude AI model, is preparing to go public at a valuation of $1.4 trillion, which could make the IPO one of the largest in history. However, this particular refrain has of late seemed more ominous than cause for optimism, and the Anthropic IPO could be no exception.

The company has said it will offer 825 million shares at $70-78 apiece, to raise up to $64.4 billion. The valuation includes shares to be issued through employee options and other arrangements, and its market capitalisation based on outstanding shares is likely to be near $1 trillion. (It was valued at $965 billion in a private funding round in May.)

Anthropic's financial prospects depend on continuing to spend extraordinary sums of money. Its amended prospectus filed with the U.S. Securities and Exchange Commission on November 10 revealed roughly $900 billion in spending commitments, almost entirely for computing infrastructure, until 2045. Of this, the company expects to incur half by 2030 and $70.7 billion in the twelve months from September 30.

The filing also mentions another $150-175 billion in potential payments under arrangements sans fixed dollar commitments.

These figures clarify a colossal exposure to future demand that neither Anthropic nor other Big AI companies have thus far been able to guarantee.



**Money counts:** Anthropic's financial prospects depend on continuing to spend extraordinary sums of money. REUTERS

And while Anthropic's revenue has also been growing, from $2.5 billion in the first three quarters of 2025 to $33.2 billion in the corresponding slice of 2026, the proposed fully diluted valuation exceeds annualised sales 17-fold.

The current business model is, largely, to charge customers according to how many tokens they use to run their tasks on its AI models. From January to September 2026, this revenue constituted 79% of the total revenue, giving Anthropic a reason to encourage users to maximise token use, irrespective of changes in the value of the output generated – a tendency famously called tokenmaxxing. But three factors complicate this picture. First, Anthropic has said AI models released within the last six months accounted for more than 80% of its third quarter revenue, which means its engineers need to keep building progressively more capable models. Second, it has not established that it will be able to sustain its profitability after honouring its infrastructure commitments.

The third factor is the most important, however: neither Anthropic nor its competitors, including OpenAI, currently has a lasting competitive advantage, a.k.a. a moat.

In fact, the difficulties of securing a moat are better illustrated by OpenAI CEO Sam Altman's position of late, in favour of new regulatory and compliance demands. These demands could impose costs that larger AI companies will bear more easily than smaller ones.

**Legitimate reasons**

Legitimate reasons to regulate AI include security failures and the risks posed by autonomous systems but governments should endeavour overtly to prevent such regulatory capture given the perverse incentives facing AI companies.

Overall, neither Anthropic nor its competitors have presented evidence of a sturdy moat. Instead, thanks to capable open-source development, models are becoming cheaper and competitors are catching up, and efficiency gains threaten the pricing power on which their valuations depend.

GS 3: Economy

Key Pointers:

- Why is Anthropic's business model vulnerable?
- What is tokenmaxxing?
- Why is AI regulation necessary?
- IndiaAI Mission (2024)
- Bhashini
- Digital Personal Data Protection Act, 2023

# Iron ore capacity under-utilisation in major-producing States prompts concerns

**Saptaparno Ghosh**
NEW DELHI

With India's iron ore demand projected to rise to 772 million tonnes (MT) by 2047, miners in Odisha, the country's largest iron ore reserve holder, are yet to utilise nearly 40% of their existing capacities, raising concerns over resource wastage and potential revenue losses.

The issue has come under judicial scrutiny, with both the Supreme Court earlier this month and the Odisha High Court in January flagging the underutilisation of mining capacities.

The Odisha High Court, while agreeing with petitioners who highlighted the sluggish operationalisation of mines despite environmental clearances, observed that the delay had resulted in an average annual revenue loss of ₹4,000 crore to the State.

Data cited by petitioner Citizens' Action Forum (Bhubaneswar) show that of the 246 million tonnes per annum (MTPA) of mining capacity granted environmental clearance in FY25, only around 159 MTPA had been operationalised.

The underutilised capacity is particularly significant as it largely involves hematite, the highest-grade variety of iron ore.

Odisha accounted for more than 50% of India's domestic iron ore production during FY26. Chhattisgarh contributed around 17.1%, followed by Karnataka at 16.6%. Capacity utilisation in the two states - albeit with significantly lower volumes than Odisha - stood at 62% and 80%, respectively, according to calculations based on Big-Mint data.

GS 3: Economy

Key Pointers:

- What is the geographical distribution of iron ore production?
- Why is iron ore important for India?
- What are the different types of iron ore?
- Why is mining capacity under-utilised?
- Mines and Minerals (Development and Regulation) Act, 1957

# Ancient south Indian diets featured milk, wild game: study

**Divya Gandhi**

The archaeology of food is well documented in North India's ancient Indus Valley Civilisation, where the culinary repertoire, deduced from rigorous studies of pottery shards, comprised dairy, meat, and plant-based products as far back as 2500 BC.

A new study has now pieced together the culinary composition of prehistoric South India's cuisine and revealed advanced plant processing and a custom of consuming cow milk in 600-100 BC, in two important archaeological sites: Keezhadi in Tamil Nadu from 6th to 2nd century BC and in Gottiprolu in Andhra Pradesh from 2nd to 1st century BCE.

The study, published in Heritage Science, said: "This indicates that the societies primarily depended on agriculture, cattle rearing, and dairying practices." In Keezhadi, the authors analysed 70 animal skeletal fragments and found a predominance of cattle, buffaloes and goats, and the presence of wild animals such as antelope and wild boar, "with cut marks [suggesting] hunting supplemented" people's diets.

At Gottiprolu, the team found remains of several fauna, including cow/ox, buffalo, sheep, goat, horse, dog, and pig. Researchers used organic residue analysis to examine dietary biomarkers in pottery. Trapped in the vessels' pores, these molecules remained preserved for millennia.

While both Gottiprolu and Keezhadi are situated on river banks, "the chosen pottery may not have been used to cook aquatic species such as fish," the study said. However, the study analysed only four shards as a proof-of-concept, co-author and Vellore Institute of Technology associate professor Vijayanand Chandrasekaran told *The Hindu*: "It is entirely possible that the inhabitants consumed fish but cooked them in other, unsampled vessels or prepared them using methods that did not require pottery."

Artefacts excavated recently from Keezhadi have pointed to a prosperous urban settlement in the Sangam age, replete with brick structures and thriving trade. Researchers have also found evidence of weaving and dyeing industries as well as gold ornaments, ivory bangles, and dice games.

According to Dr. Chandraseharan, the new finding is also an advance because it moves beyond structural artefacts to direct biomolecular evidence. And "it provides the first direct chemical evidence of prehistoric dairying practices in South India, previously thought to be strictly limited to North India and the Indus Valley civilisation," he added.

GS 1: Art and Culture

Key Pointers:

- What did people eat in ancient South India?
- What is Organic Residue Analysis (ORA)?
- What are dietary biomarkers?
- Why is Keezhadi and Gottiprolu significant?



# $CO_2$ emissions briefly dipped in 2026 due to West Asia war

Between 2019 and 2025, global fossil fuel emissions grew 0.8% annually. Now, researchers have projected a 0.4% drop in 2026, likely temporary, due to high oil prices linked to the West Asia conflict, which constrained supply chains and drove fuel prices up by 10% to 50% in major economies, including the U.S., China, and Europe. Oil-linked emissions thus dropped by 1.9%, pulling total $CO_2$ levels down despite a 0.6% increase in coal emissions.

GS 3: Environment

Key Pointers:

- How did the West Asia conflict reduce $CO_2$ emissions?
- Why did coal emissions continue to increase?
- Why is this decline potentially temporary?

AMRITA IAS

# Potent perovskites demand domestic manufacturing push

As China tightens export controls on next-generation photovoltaic technology, local enterprises are racing to establish independent supply chains; national testing facilities are now vital to ensure lightweight modules become viable

Sonam Raina
BENGALURU

Perovskite solar cells are an exciting technology in the solar industry because they extract more power from a given area than silicon. They get their name from the crystals they are made of, metal-halide perovskites. They absorb sunlight strongly, so require an active layer only a few hundred nanometres thick, three orders of magnitude thinner than silicon wafers.

China is already regarding them as a strategic asset. On October 16, the country proposed adding 12 photovoltaic technologies to its export control list, including manufacturing technologies for perovskite and tandem solar-cell modules above certain production and efficiency thresholds. Tandem cells have both perovskite and silicon layers and can generate even more electricity from the same area.

India's solar industry depends heavily on imports from China. It has no polysilicon manufacturing capacity and imports the vast majority of wafers as well as the machines used to make them, according to a report by The Energy and Resources Institute, New Delhi. The country has built a self-reliant solar-power supply chain but the road there has been marked with temporary cell shortages and legal challenges. If perovskites become the next major solar technology, India will need to build the capacity to manufacture them domestically.

Dinesh Kabra, co-founder of Advanced Renewable Tandem-Photovoltaics (ART-PV) India, a start-up developing high efficiency tandem cells, said he expects perovskites to complement silicon over the coming decade rather than replace it. For example, the relative thinness of perovskites' active layers could bring solar power to surfaces where conventional panels do not work, such as windows and in space.

ART-PV has tested a machine from a Taiwanese supplier that applies a thin layer of perovskite material onto a solar cell. The team used its own formulation of the material and is now finalising a deal to buy the equipment, Dr. Kabra said.

Sooraj Kumar, co-founder and chief executive officer of P3C Technology & Solutions, another company developing perovskite solar technology, said it has built most of its core manufacturing equipment in India. P3C has also scaled cells from about a centimetre across to mini-modules spanning one square foot, each of which has an active area with an efficiency of 17%-18%.

## Durability challenge

The company's next step is to build a larger sub-module that is field-ready. Experts at the company have projected that manufacturing costs could fall to ₹12 per watt at the gigawatt scale, assuming favourable yield, production volumes, and reliability and the cost of the complete module being competitive in the future market. Dr. Kumar also suggested that high-purity input materials like iodide salts, lead iodide, and glass with transparent and conductive oxide coating, which are mostly being imported today, will eventually be developed in India.

Dr. Kabra said buyers perceive solar panels as infrastructure rather than as consumer gadgets, and expect the panels to last for decades. Silicon panels are indeed generally designed for a service life of 25 to 30 years. Perovskites, however, may not last as long: moisture can trigger chemical reactions that break down the light-absorbing material. So experts have suggested unconventional uses for perovskite setups for now.

Ke Xiao, assistant professor at the Nanjing University School of Advanced Manufacturing, said they can be deployed in orbit because tandem cells are more efficient and, as studies have found, perovskite cells can tolerate particle radiation better than silicon or gallium arsenide cells. That said, researchers say standards for testing how perovskite solar cells perform under orbital conditions have yet to be developed.

Some important barriers still need to be overcome, including encapsulating perovskites to protect from heat, according to Dr. Xiao. In June, his team reported a certified 26.2% efficiency on a 65 $cm^2$ all-perovskite tandem module, which is a noteworthy high and a milestone towards manufacturing.

Most high-performing perovskite formulations also contain a small amount of lead. Dr. Kumar said P3C seals its modules with lamination and barrier sheets to prevent leaching.

## Domestic capacity

He added that he wants the Ministry of New and Renewable Energy to back pilot and megawatt-scale production lines, and that the industry will benefit from national testing facilities, certification standards, and demonstration projects on public buildings.

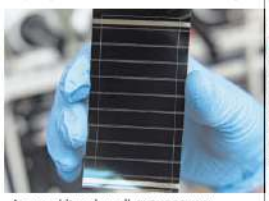
The IIT-Bombay has also set up a 6,300 sq. ft facility for perovskite-silicon tandem research. Indian Institute of Science, Bengaluru, researchers are working on scalable fabrication. GREW Solar has partnered with U.S.-based Caelux to target 4-GW of hybrid perovskite-silicon tandem module production in India by 2028. Ultimately, Dr. Kabra said money is not the main obstacle.

He wants the government to instead trust Indian researchers and manufacturers to build the technology.

*(Sonam Raina is a Bengaluru-based journalist who covers sustainability in business. sonam.raina@gmail.com)*

### Place in the sun

If perovskites become the next major solar technology, India will need to build the capacity to manufacture them domestically



A perovskite solar cell. PUBLIC DOMAIN

- Perovskite solar cells have higher power yields than silicon while potentially requiring less energy to manufacture
- With China restricting technology exports, India urgently needs to develop a domestic perovskite manufacturing supply chain
- Innovative Indian startups are currently developing scalable perovskite solar modules and building local core manufacturing equipment
- Despite their impressive efficiency, perovskite materials face severe durability challenges because moisture triggers chemical degradation
- Due to these challenges, experts say that early Indian applications will target environments related to space exploration
- To succeed, the emerging domestic industry needs dedicated testing facilities, certification standards, and the government's trust

GS 3: Science and Technology

Key Pointers:

- What are perovskite solar cells?
- What are tandem solar cells?
- Why is perovskite technology strategically important for India?
- What is India's existing vulnerability in solar manufacturing?
- National Solar Mission
- India Semiconductor Mission
- National Green Hydrogen Mission

# There is more to vanilla than its taste and aroma



SPEAKING OF SCIENCE

D. Balasubramanian

Vanilla is a common additive to make cakes, ice creams, and fragrant body lotions. Children enjoy a good vanilla ice cream. People often use vanilla as the primary flavour in baked goods and in chocolates. It is not just the flavour: vanilla also has health-promoting properties that have been known for centuries.

Vanilla comes from the fruits of the orchid herb that botanists call *Vanilla planifolia*, found mostly in tropical countries. Its medicinal properties have been known since ancient times. Traditional physicians of the 15th century in the Aztec region of Mexico had used the orchid pods as a remedy for stress and mental strain.

In India, the vanilla plant was brought by the Colonial British and the plant is now grown in Keralam, Karnataka, and Tamil Nadu.

In 2013, a group of scientists from Mysuru described the cultivation, chemistry, and nutraceutical properties of vanilla (DOI: 10.1080/10408398.2011.563879).

In 2024, a group of researchers in Uttar Pradesh also summarised the use of vanilla by Ayurvedic physicians for its therapeutic properties (*Int. J. Environ. Clim. Change*, vol.14, no. 2, pp. 809-817, 2024).

The vanilla flowers are greenish in colour with a soothing fragrance. Newborns breathe calmer and better when they smell vanilla, and adults sleep better. It is also known to reduce inflammation.

Vanilla's active component is an aromatic benzaldehyde called vanillin, which offers a sweet smell, taste, and flavour, while its sugar content is negligible. Vanillin is approved by the World Health Organization, the U.S. Food and Drug Administration, and the Food Safety and Standards Authority of India as a food additive. The Barnes Jewish Hospital in Washington University in the U.S. has listed that a tablespoon of vanilla extract has several minerals and vitamins but no fatty acids or cholesterol.



The vanilla flower belongs to the orchid family. FILE PHOTO

Vanilla's medicinal properties are largely due to vanillin. It soothes coughing, reduces blood pressure, and acts as an antidepressant. It also has reliable healing properties against certain wounds and is efficient as an antibacterial and anti-fungal agent. A review by a group of scientists from Nigeria (DOI: 10.1016/j.ejmcr.2022.100055) has shown that vanillin helps with regulating blood pressure, digestion, and has antimicrobial, antioxidant, and neuroprotective properties.

Likewise, a group of pharmacologists from Adelaide in Australia has also shown the biomedical advantages of vanillin in chronic wound healing and tissue regeneration (DOI: 10.1016/j.ijpharm.2026.127263). Given the vanilla plant is not available in several countries, and the medical and cosmetic advantages of vanillin, a short review of its chemical synthesis and biotransformation was recently published by a group from Jiangsu University, China in (DOI: 10.1016/j.rser.2023.113905).

The group also chemically modified lignin, which is present in plant cell walls, to produce vanillin. Scientists have also made vanillin by genetically modifying microbes (DOI: 1016/j.ces.2022/8049).

A 2019 review by Banerjee and Chattopadhyay from the University of Gauhati summarised the biotechnological aspects of vanillin (*J. Sci. Food Agric.* 99, 4999-506, 2019), including a description of how the molecule, besides its medicinal value, can also be used for metal plating, as a herbicide, a deodorant, and of course as a flavouring agent.

In addition to domestic consumption, India exports its vanilla to various countries, notably Bangladesh, Germany, and several in Africa, for several million dollars in revenue every year.

So the next time you have vanilla ice cream, you can enjoy its taste as well as its versatility.

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GS 3: Science and Technology

Key Pointers:

- What is vanilla?
- What is vanillin and why is it important?

AMRITA IAS

## Question Corner

# Smoke in the air

**Why do firecracker emissions sometimes linger in the air?**

Emissions from firecrackers can linger when local atmospheric conditions keep the pollutants from dispersing or being moved away.

For example, winds can carry pollutants away from their source and dilute them in cleaner air. When the winds are weak, smoke and fine particles can accumulate near where firecrackers are burst. If people also repeatedly burst firecrackers over several hours, the pollutants can fill the air faster than they can be dispersed. Normally, warm air near the ground lifts pollutants upward. But during an inversion, a layer of warmer air sits above the surface air, trapping pollutants near the ground.

When the lowest part of the atmosphere, called the boundary layer, becomes shallow, the pollutants also become confined to a smaller volume of air. Many particles released by firecrackers can also absorb moisture and swell, rendering them 'more visible'. Taken together, the aftermath of an explosive spree can seem to be the worst when the winds are weak, the boundary layer is shallow, and an inversion is in play.

Readers may send their questions / answers to science@thehindu.co.in

GS 3: Environment

Key Pointers:

- Why do firecracker emissions remain suspended in the air?
- What is Temperature inversion?
- What pollutants are released by firecrackers?