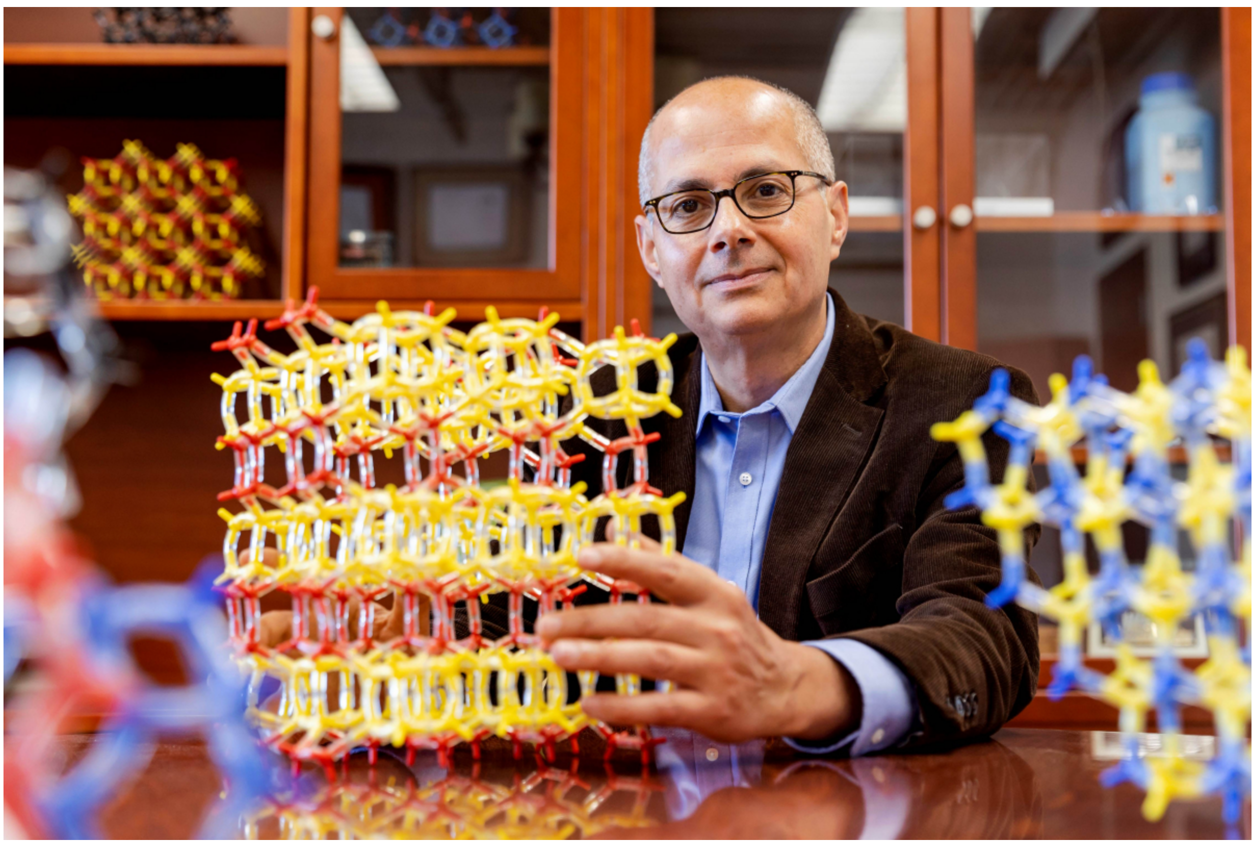
TANG PRIZE

2024.06.18

# Omar M. Yaghi Receives 2024 Tang Prize in Sustainable Development for Groundbreaking Work in Innovative Materials for Carbon Capture, Energy Storage, and Water Harvesting

- 

The Tang Prize, a biennial award established in 2014, has honored five cycles of laureates across various fields. This year, the announcement of the prize winners will unfold over four consecutive days, commencing with the

Sustainable Development category. **Today (June 18th), the Tang Prize Foundation announced Omar M. Yaghi, an esteemed American chemist, as the recipient of the 2024 Tang Prize in Sustainable Development. Prof. Yaghi is awarded for his extraordinary contributions to sustainable development, particularly his pioneering work with Metal-Organic Frameworks (MOFs) and other ultra-porous frameworks that can be tailored for carbon capture, hydrogen and methane storage, and water harvesting from desert air.** Prof. Yaghi's research has revolutionized the field of chemistry and materials science, offering transformative solutions for sustainable development through the creation of customizable materials with exceptional properties.

Prof. Yaghi is currently the James and Neeltje Tretter Chair Professor of Chemistry, Department of Chemistry, University of California, Berkeley, a Faculty Scientist Affiliate at Lawrence Berkeley National Laboratory, and the Founding Director of the Berkeley Global Science Institute. He is also the co-director of the newly established Bakar Institute of Digital Materials for the Planet at College of Computing, Data Science and Society. Prof. Yaghi holds 60 US patents and has been honored with many prestigious awards from 17 countries, some of which are among the highest in Chemistry. **Prof. Yaghi has introduced a new method for controlling four of the smallest gas molecules in the atmosphere that significantly impact our planet's sustainable development: carbon dioxide, hydrogen, methane, and water. This was made possible through his pioneering development of a new field of chemistry known as reticular chemistry. Reticular chemistry is a new approach to creating materials by linking organic and**

**inorganic units into strong, porous crystalline structures called metal-organic frameworks (MOFs) and covalent organic frameworks (COFs). Prof. Yaghi demonstrated how these novel framework materials can trap, concentrate, and manipulate hydrogen, methane, carbon dioxide, and water from the air,** offering innovative solutions to pressing issues related to the United Nations' Sustainable Development Goals (SDGs), including energy, environment, and water resources.

## Unprecedented Success: First Sustainable Application Yields Amazing Results

**As a pioneer of MOFs and COFs, Prof. Yaghi is the first scientist to apply these innovative materials to the field of sustainable development, demonstrating tangible and impressive results.** His pioneering work has yielded impressive results. For example, he demonstrated that incorporating one of his MOFs increases the carbon dioxide storage capability at room temperature by 18 folds. Furthermore, chemically modified MOFs and COFs can selectively capture voluminous amounts of carbon dioxide from combustion gases. MOFs are already being utilized in the venting systems of cement plants in Canada. In the context of methane storage, a fuel tank filled with MOFs can triple the amount of methane stored at room temperature and safe pressures compared to a tank without MOFs under the same conditions. This achievement allows automobiles to triple the distance traveled without refueling. Additionally, for hydrogen storage, MOF and COF materials can store up to twelve weight percent of hydrogen (at 77 K and 100 bar) in a tank filled with MOFs, making this technology relevant to the safe and stationary storage of hydrogen.

Using just a kilogram of MOF materials, Prof. Yaghi can harvest water in water-scarce areas with low humidity, such as deserts, using only ambient sunlight. The water is concentrated in the pores of MOFs, and its quality exceeds the standards for drinking water set by the U.S. Food and Drug Administration (FDA) and the Environmental Protection Agency (EPA). In collaboration with industrial companies including General Electric and startups in the past few years, he has developed portable MOFs water harvesters capable of producing hundreds of liters of water per day in an energy-efficient and cost-effective manner, sufficient for meeting the needs of a family. Prof. Yaghi has stated that the amount of water in the air is nearly equivalent to the total fresh water in all rivers and lakes on the Earth's surface. He aims to help water-scarce areas achieve “water independence” through this technology.

## Material Advantage: Pioneering New Solutions for Sustainable Development

The new materials, MOFs and COFs, developed and designed by Prof. Yaghi, have many advantages. First, they are highly crystalline with a stable and durable structure. For instance, the water harvesting device employing MOFs designed by Prof. Yaghi maintains optimal performance even after 30,000 cycles of use. Second, these materials possess record-breaking porosities, robust yet flexible crystallinity, and can scale to multi-ton quantities. Third, their structures can be chemically modified at the molecular level (Lego-like), showcasing the chemical flexibility and precision with which their structures could be designed and manipulated.

Fourth, Prof. Yaghi's research results are not only groundbreaking in basic science but are also rapidly demonstrated in practical applications for sustainable development, such as quantitative production through industry-academia cooperation with the well-known German company BASF. To date, hundreds of laboratories worldwide are actively working on applications for clean energy, clean air, and pure drinking water applications using the materials and technologies he has developed. Several international chemical, materials, and automotive companies and more than 30 start-ups have also launched related programs and products. Currently, it is estimated that more than 100,000 types of MOFs and COFs materials are produced by Reticular Chemistry worldwide. According to data from the Market Watch website under Dow Jones & Company in the United States, the market capitalization of MOFs and COFs was projected to be $270 million in 2021 and $350 million in 2022. These materials, based on technology developed by Prof. Yaghi, are also being applied in the field of medical science. This emerging technology is expected to continue flourishing with endless potential in the future, with market value projections exceeding one billion by 2030.

## A Unique Background Driving the Future

Prof. Yaghi was born into a refugee family in the desert on the outskirts of Amman, Jordan, with roots of Palestine. His personal experience with water scarcity and poverty has led him to see the importance of science and research in improving the lives of people in areas with limited opportunities. The widespread use of MOFs and COFs around the globe has given Prof. Yaghi the means to engage emerging scholars in developing countries. He founded the Berkeley Global Science Institute at the University of California and developed unique mentoring programs, which are being implemented in centers and collaborations of research he established in countries such as Vietnam, Malaysia, Saudi Arabia, Argentina, Mexico, and Jordan. These centers aim to invite the youth to ‘plug’ into research locally at an early age and begin transforming themselves and contributing meaningfully to their scientific environment. Through these mentoring programs, young scholars are invited to participate in research, make a difference in their own lives, and help solve the larger societal problems.

**About the Tang Prize**

Since the advent of globalization, mankind has been able to enjoy the convenience brought forth by the advancement of human civilization and science. Yet a multitude of challenges, such as climate change, the emergence of new infectious diseases, wealth gap, and moral degradation, have surfaced along the way. Against this backdrop, Dr. Samuel Yin established the Tang Prize in December 2012. It consists of four award categories, namely Sustainable Development, Biopharmaceutical Science, Sinology, and Rule of Law. Every other year, four independent and professional selection committees, comprising many internationally renowned experts, scholars, and Nobel winners, choose as Tang Prize laureates people who have influenced and made substantive contributions to the world, regardless of ethnicity, nationality or gender. A cash prize of NT$50 million (approx. US$1.7 million) is allocated to each category, with NT$10 million (approx. US$ 0.35 million) of it being a research grant intended to encourage professionals in every field to examine mankind's most urgent needs in the 21st century, and become leading forces in the development of human society through their outstanding research outcomes and active civic engagement.

# 美國化學家獲頒唐獎「永續發展獎」 創新材料對碳捕集、能源儲存與水資源利用貢獻非凡

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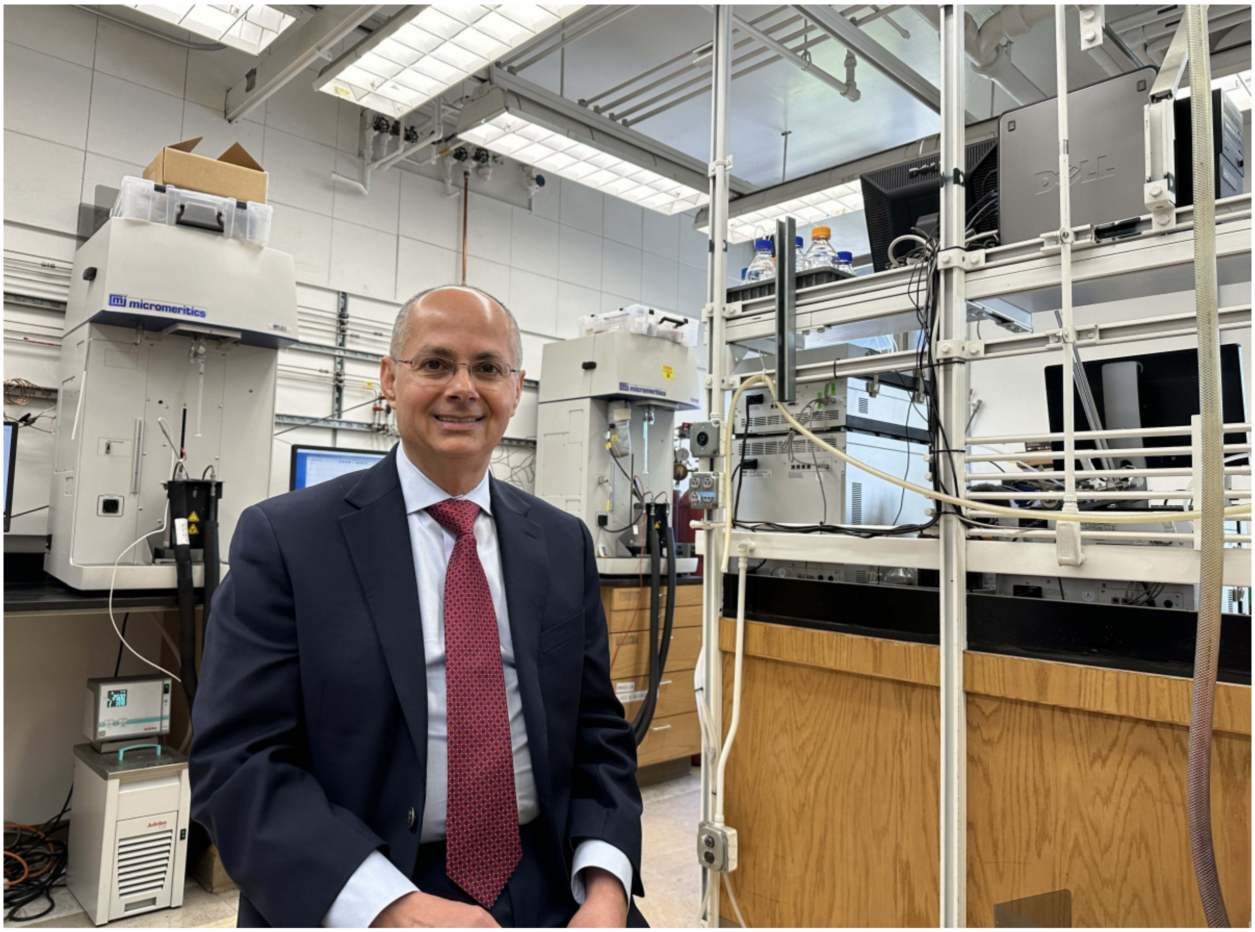
- 

兩年頒布一次，自2014年誕生首屆得主，至今已頒布五屆得主的世界學術大獎-唐獎，一連四天持續揭曉第六屆唐獎得獎人名單。**今(18)日首先公布「永續發展獎」，得獎人為美國化學家奧馬爾，亞基(Omar M. Yaghi)，唐獎肯定其在金屬有機及相關超多孔骨架材料上開創性的建樹，此種材料已廣泛設計成碳捕集、氫氣和甲烷儲存及乾旱地區集水之應用，對永續發展作出非凡貢獻。**

奧馬爾·亞基教授是加州大學柏克萊分校化學系詹姆斯與內爾蒂崔特獎座教授、柏克萊勞倫斯國家實驗室資深科學家、柏克萊全球科學學院的首任主任，也是柏克萊巴卡學院的首任共同主任及首席科學家，曾獲頒17個國家的重要獎項及擁有60項美國專利。**他開創的化學新領域-網格化學，以一種新的合成方式生成材料，透過強鍵結合力，將有機和無機單元編結成為堅固的多孔結晶金屬有機骨架（MOFs）及共價有機骨架(COFs）材料，且運用此材料的多功能特性來捕捉、集中及利用二氧化碳、氫氣、甲烷及水等四種對地球永續發展有最大影響的小氣體分子，<u>對解決當今世界邁向永續發展所面臨迫切的能源、環境及水資源問題等永續發展目標(SDGs)，均提供嶄新的解決方法。</u>**

<u>**永續首應用成果驚人**</u>

**身為MOFs和COFs材料創始人之一，亞基教授是最先將此前瞻性新材料應用到永續發展領域的科學家**並展現具體驚人的成果：<u>**在二氧化碳捕集方面**</u>，使用特定MOFs材料的容器，在常溫下即能增加18倍的儲存量；經過化學方式修飾過的MOFs和COFs材料，更可從燃燒氣體中精準捕集大量二氧化碳，目前MOFs已應用在加拿大水泥廠的排氣口。<u>**在甲烷儲存方面**</u>，在常溫及安全氣壓下，含有MOFs材料的容器可以比一般容器多出3倍的儲存量。<u>**在氫氣的儲存方面**</u>，做為乾淨能源，氫氣儲存不易且具高危險性為其限制，但使用MOFs和COFs材料後，在77K(絕對溫度)及100大氣壓此困難度不高的條件下，即可安全、穩定地儲存12重量百分比的氫氣，是項非常有用的技術。

<u>**在缺水地區集水方面**</u>，亞基教授僅用一公斤的MOF材料，<u>**只需有平常的陽光，就可在沙漠等低濕度的空氣中收集水氣**</u>

，使其集中在MOFs的孔隙內且水質遠超過美國食品藥物管理署及環保署所訂定的飲用水標準。近幾年，亞基教授和美國通用電器公司和新創公司合作，製造可攜式的MOFs集水裝置，以節能及較經濟的方式，成功在沙漠地區每日收集數百公升的飲用水，滿足一家一日的用水量。亞基教授曾公開表示空氣中的含水量幾乎相當於地表所有河流及湖泊淡水的量，希望藉由科技去幫助缺水地區達到「Water Independent」的目標。

**材料優勢為永續發展課題提供新解方**

亞基教授開創及設計的MOFs和COFs新材料具有諸多優勢，其材料擁有破紀錄的孔隙度，堅固而具有高結晶度，並有可達數噸的高擴展性。其設計的集水裝置，經測試在3萬週期的使用後仍能維持最佳成效。同時，其化學結構能像樂高玩具般，在分子層次上靈活設計、修飾以因應不同使用目的。

亞基教授的研究成果不僅在基礎科學上有開創性的成果，更快速展現在永續發展的實際應用上，如與德國知名的巴斯夫集團(BASF)等公司產學合作，量化生產。至今全球有數百個實驗室，藉由他發展出的材料及技術，積極投入清潔能源、清潔空氣和純淨飲用水等應用。一些國際化學、材料及汽車製造集團及三十多家新創公司，也推出相關方案及產品。目前估計全球由網格化學所產出的MOFs及COFs材料超過10萬種。在市值方面，根據美國道瓊公司轄下的市場觀察網站數據顯示，以亞基教授發展的科技為主題，估算出2021年MOFs和COFs的市場規模是2億7仟萬美元，2022年更達到了3億5仟萬美元，甚至應用到醫學領域，這項新興技術目前仍在持續蓬勃發展，未來擁有無窮潛力；預計到2030年，市場價值將超過10億美元。

**成長背景促提攜後進**

亞基教授出生於約旦安曼郊區沙漠中的難民家庭，其家庭最早來自於巴勒斯坦。對於缺水、貧窮的切身之痛，讓他深刻體認到科學與研究對改變機會匱乏地區生活的重要性。全球MOFs和COFs的廣泛應用，使亞基教授擁有協助不同國家新秀學者參與研究的途徑，他在加州大學柏克萊分校創立柏克萊全球科學學院，發展出獨特的「引路人計畫」，並在越南、馬來西亞、約旦、沙烏地阿拉伯、阿根廷及墨西哥等研究中心執行，邀請當地的年輕學者加入研究，透過引路人計畫改變自己，也對解決更廣泛的社會問題做出貢獻。

**【關於唐獎】**

有感於全球化的進展，人類在享受文明與科技帶來便利的同時，亦面臨氣候變遷、新傳染疫病、貧富差距、社會道德式微..等種種考驗，尹衍樑博士於2012年12月成立唐獎，設立永續發展、生技醫藥、漢學及法治四大獎項，每兩年由專業獨立評選委員會(邀聘國際著名專家學者，含多名諾貝爾獎得主），不分種族、國籍、性別，遴選出對世界具有創新實質貢獻及影響力的得主。每獎項提供5千萬獎金，其中含1千萬支持相關研究教育計畫，以鼓勵專業人才投入探索21世紀人類所需，以頂尖的創新研究成果及社會實踐引領全人類發展。

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