

that they would collaborate on a large carbon-capture-and-storage project on the Texas Gulf Coast. The firms aim to make blue hydrogen, produced by reforming natural gas and storing the by-product carbon dioxide. Linde will distribute this hydrogen to customers via its regional pipeline network. The firms aim to store some 15 million metric tons of CO₂ annually in underground formations. In Austria, Linde is building a plant to make green hydrogen—derived from water electrolysis powered by renewable energy—for sale to the semiconductor maker Infineon

Technologies. To help shore up helium supply, Linde is adding an extraction unit at a natural gas liquefaction plant in Texas. The project will increase the world's supply of helium by more than 3%.

14 Air Liquide

2021 chemical sales: \$27.1 billion

Late last year, the French industrial gas giant Air Liquide got into a business that is as high tech as a chemical business can get. It signed an agreement with the Canadian nuclear power

operator Laurentis Energy Partners to buy helium-3, a light isotope of helium formed via the β decay of the heavy hydrogen isotope tritium. Air Liquide will market 5,000–10,000 L of the ³He annually. The isotope is needed for quantum computing, which must operate at temperatures as close to absolute zero as possible. Conventional liquid ⁴He cooling can get down to 1–4 K, and getting below that requires mixing in some ³He. Separately, Air Liquide is building what it calls the world's largest biomethane plant, at a Chicago-area landfill. The industrial gas maker estimates that the collected methane could generate 380 GW h of energy annually. It is also building a methane recovery plant in Wisconsin.

Spending

Chemical capital spending and R&D budgets increased for most companies in 2021.

	CHEMICAL CAPITAL SPENDING			CHEMICAL R&D SPENDING		
	2021 (\$ MILLIONS)	CHANGE FROM 2020	% OF CHEMICAL SALES	2021 (\$ MILLIONS)	CHANGE FROM 2020	% OF CHEMICAL SALES
Air Liquide	\$3,396	8.8%	12.5%	\$360	0.3%	1.3%
Air Products	2,464	-1.8	23.9	94	11.4	0.9
Arkema	903	26.1	8.0	287	0.8	2.6
Asahi Kasei	1,099	20.2	10.1	308	2.7	2.8
BASF	4,178	12.9	4.5	2,622	6.2	2.8
Borealis	781	7.5	7.7	21	127.8	0.2
Braskem	634	24.0	3.2	55	18.4	0.3
Covestro	904	8.5	4.8	403	30.2	2.1
Dow	1,501	19.9	2.7	857	11.6	1.6
DSM	512	-5.5	4.7	382	-18.8	3.5
DuPont	891	-25.4	5.4	618	-28.1	3.7
Eastman Chemical	555	44.9	5.3	254	12.4	2.4
EuroChem Group	1,247	6.8	12.2	n/a	n/a	n/a
Evonik Industries	1,023	-9.5	5.8	549	7.2	3.1
ExxonMobil	1,287	-29.0	3.5	n/a	n/a	n/a
Hanwha Solutions	609	29.8	5.6	47	-25.6	0.4
Indorama Ventures	624	19.0	4.3	21	12.2	0.1
Ineos	1,845	-7.0	4.6	92	63.4	0.2
Johnson Matthey	383	19.8	3.7	277	3.6	2.7
Lanxess	567	5.0	6.3	136	6.5	1.5
LG Chem	5,043	4.3	13.5	1,186	21.6	3.2
Linde	3,149	-8.9	11.3	n/a	n/a	n/a
Lotte Chemical	675	-3.6	4.3	81	15.5	0.5
LyondellBasell Industries	1,856	5.3	4.8	124	9.7	0.3
Mitsubishi Chemical Group	1,863	-12.0	6.1	n/a	n/a	n/a
Mitsui Chemicals	975	42.9	6.6	347	12.7	2.4
Mosaic	1,289	10.1	10.4	n/a	n/a	n/a
Sabco	3,083	-12.0	7.1	n/a	n/a	n/a
Shell	3,573	35.3	21.0	106	-2.8	0.6
Shin-Etsu Chemical	1,782	-17.1	9.4	568	21.9	3.0
Sinopec	8,006	97.1	12.2	n/a	n/a	n/a
Solvay	664	23.6	4.9	384	8.3	2.8
Sumitomo Chemical	778	19.7	4.1	n/a	n/a	n/a
Umicore	342	-8.5	2.5	243	4.1	1.8
Wanhua Chemical	n/a	n/a	n/a	491	55.1	2.2
Yara	809	9.5	4.9	94	3.3	0.6

Sources: Company documents, C&EN analysis. Note: Figures are for companies on the top 50 list reporting capital and/or R&D expenditures. n/a means not available.

15 Syngenta Group

2021 chemical sales: \$24.9 billion

The Chinese conglomerate ChemChina bought the Swiss agrochemical maker Syngenta in 2017 and later pursued a merger with another big Chinese industrial giant, Sinochem. Now Syngenta Group operates under the Sinochem umbrella. As it did when it was independent, Syngenta emphasizes technology. It is collaborating with Enko Chem, a start-up that applies drug discovery methods to agricultural applications. For instance, the partners will screen molecular libraries for compounds that act against specific enzymes in pests. They hope to halve the time to bring new molecules to market—which can now take a decade. Syngenta also recently bought two biopesticides from the Welsh firm Bionema. In the deal, it acquired nematodes that kill leatherjackets and a pathogenic fungus that kills vine weevils.

16 Reliance Industries

2021 chemical sales: \$22.6 billion

The Indian conglomerate has abandoned plans to put its refining and chemical operations—which it calls Oil to Chemicals—into a stand-alone business. It also walked away from negotiations with Saudi Aramco to sell a 20% stake in the business for \$15 billion. Instead, Reliance Industries is undertaking what may turn out to be an even bigger change in direction. Last year, it announced an ambitious goal to achieve net-zero carbon emissions by 2035. Reliance is setting aside 2,000 hectares of land at its massive Jamnagar refinery and petrochemical complex for factories that would make photovoltaic modules, batteries, electrolyzers, and fuel cells. Along these lines, Reliance bought